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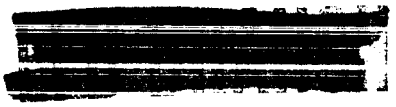

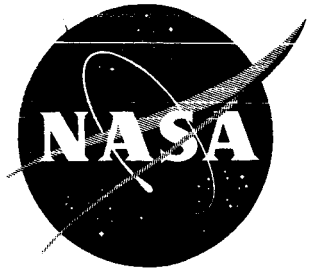

TECHNICAL MEMORANDUM

X-570

AERODYNAMIC PERFORMANCE AND STATIC-STABILITY CHARACTERISTICS OF A BLUNT-NOSED, BOATTAILED, 13° HALF-CONE AT MACH NUMBERS FROM 0.6 TO 5.0

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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TECHNICAL MEMORANDUM X-570

AERODYNAMIC PERFORMANCE AND STATIC-STABILITY CHARACTERISTICS OF A BLUNT-NOSED, BOATTAILED, 13° HALF-CONE AT MACH NUMBERS FROM 0.6 TO 5.0*

By John V. Rakich

SUMMARY

An atmosphere-entry configuration developing trim lift-drag ratios of about 1.2 at supersonic speeds was investigated experimentally at angles of attack to 15° at transonic speeds and to 54° at supersonic speeds. The configuration was essentially one-half of a 13° half-angle cone with a blunted nose and a boattailed afterportion to which were added a canopy and a pair of vertical stabilizing fins. The effects of pitch, yaw, and roll controls were also investigated.

Primary attention was directed toward the performance, trim, and static-stability characteristics at supersonic speeds for model attitudes from nearly zero to maximum lift. Also, static stability and controllability at transonic speeds were investigated. Results indicated that the configuration without controls had satisfactory supersonic characteristics although it was longitudinally unstable at transonic speeds. The configuration complete with controls could be trimmed, at supersonic speeds, over a wide range of attitudes including that for maximum lift-drag ratio and that for maximum lift coefficient. In general, a combination of elevons and pitch flaps appeared adequate to provide trim with longitudinal stability throughout the range of test Mach numbers from 0.6 to 5.0.

INTRODUCTION

Research into the problems associated with manned atmosphere-entry vehicles has led to the study of a wide variety of ballistic and lifting configurations. Among these, the high-lift, high-drag configuration proposed by Eggers and Wong has been the subject of detailed investigations (see, e.g., refs. 1 to 6). It has been found that this blunted 30°

*Title, Unclassified

half-cone develops a maximum lift-drag ratio of about 0.5 at supersonic speeds. With this lift-drag ratio appropriately applied during entry from satellite orbit, the configuration is capable of providing about 200 nautical miles of lateral range (ref. 7). However, since greater maneuverability may sometimes be desirable, a 13° half-cone which developed a lift-drag ratio of about 1.3 at supersonic speeds (equivalently, 1000 nautical miles of lateral range) was investigated in reference 8. Concurrently, this slender half-cone was modified by boattailing the afterportion (refs. 9 and 10) to provide adequate performance and longitudinal stability for a horizontal landing. It was found that these modifications greatly improved the performance at low speeds while the lift-drag ratio at supersonic speeds was essentially unaffected.

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Although many features of the boattailed half-cone were presented in reference 9, that paper represented only a preliminary evaluation of the configuration. For example, aerodynamic characteristics near maximum lift were not presented. More complete tests with this configuration have since been conducted and the results are the subject of the present paper. Longitudinal and lateral-directional characteristics are presented for Mach numbers from 0.6 to 5.0. Attention is given to the trim characteristics near maximum lift at Mach numbers of 3.0 and 5.0. It should be noted that more complete results for Mach numbers from 0.25 to 0.92 are presented in reference 11.

NOTATION

Aerodynamic forces and moments were reduced to standard coefficient form. All forces and moments were referred to body axes with the exception of lift and drag coefficients which were referred to stability axes. Coefficients include the effects of base pressure; that is, the data were not corrected to free-stream static base pressure. The symbols used in this report are defined as follows (see fig. 1 also).

A aspect ratio, $\frac{b^2}{S}$ (0.675)

A' aspect ratio including elevons, $\frac{(b + 2b_e)^2}{S + 2S_e}$ (1.44)

b width (span) of model at the base, not including elevons

b_e width (span) of a single elevon

C_A axial-force coefficient, $\frac{\text{axial force}}{qS}$

C_D drag coefficient, $\frac{\text{drag}}{qS}$

C_l rolling-moment coefficient, $\frac{\text{rolling moment}}{qSb}$

C_L lift coefficient, $\frac{\text{lift}}{qS}$

C_m pitching-moment coefficient, $\frac{\text{pitching moment}}{qSl}$

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C_n yawing-moment coefficient, $\frac{\text{yawing moment}}{qSb}$

C_N normal-force coefficient, $\frac{\text{normal force}}{qS}$

C_{p_b} base-pressure coefficient, $\frac{p_b - p}{q}$

C_Y side-force coefficient, $\frac{\text{side force}}{qS}$

$\frac{L}{D}$ lift-drag ratio

l body length

M free-stream Mach number

p_t total pressure

p free-stream static pressure

q free-stream dynamic pressure

Re Reynolds number

S body plan-form area (not including elevons)

S_e area of a single elevon

S_b body base area

T_t total temperature

x distance from model nose along cone axis

y radial distance perpendicular to cone axis

α angle of attack (with respect to the cone axis)

β angle of sideslip

δ control deflection angle (see fig. 1)

Δ incremental value due to controls

Subscripts

α derivative with respect to angle of attack

β derivative with respect to angle of sideslip

b base

e elevon

p pitch flap

y yaw flap

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EXPERIMENT

Models

The wind-tunnel models were essentially one-half of a 13° half-angle cone with a spherically blunted nose. Geometric details of the models are given in figure 2, and photographs of a typical model configuration are shown in figure 3(a). The nose was modified slightly so as to provide a continuously varying curvature at the sphere-cone juncture. The afterportion of the undersurface profile in the plane of symmetry consisted of a circular arc tangent to the cone at 0.6 body length from the nose. Cross sections were specified at several stations aft of 0.6 of the body length, and the body was smoothly faired between these stations. The curved portion of the upper surface was described by a circular arc. The teardrop canopy was a segment of a hemisphere cylinder. Vertical stabilizing fins, with 3° toe-in, were added to the boattailed body to complete the basic model configuration. Removable, fixed angle pitch flaps, yaw flaps, and elevons were tested in various combinations.

Three models were constructed to allow testing over a wide range of angles of attack. The largest model (model 1)(fig. 3(a)) was tested at angles of attack up to 20°. It was possible to insert the force balance into the base of this model without modifying the model surface. For tests

at angles of attack from 17° to 32°, a smaller model was used (model 2) (fig. 3(b)) which had a protuberance on the top to provide sufficient volume for insertion of the balance into the model parallel to the cone axis. The balance was inserted into model 3 at a 50° angle with the cone axis (fig. 3(c)) for tests at angles of attack from 32° to 54°. The effects of protuberances similar to those of models 2 and 3 were investigated in reference 12, and were found to be small for the Mach numbers and angles of attack at which the models were tested.

A boundary-layer trip was used on the model tested at transonic speeds. The trip was formed with a 0.010-inch diameter wire cemented around the nose a distance 0.10 body length from the tip of the nose.

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Tests

Tests were conducted in the Ames 2- by 2-Foot Transonic Wind Tunnel (ref. 13), at Mach numbers from 0.6 to 1.3, and in the Ames 10- by 14-Inch Supersonic Wind Tunnel (ref. 14), at Mach numbers from 3.0 to 5.0. Wind-tunnel test conditions, angles of attack, and angles of sideslip are tabulated below.

M	α, deg	β, deg	p_t, psia	T_t, °F	Re/l, ft^{-1}
0.6	-1 to 15	±5	5.2	70	1.25×10^6
0.9	↓	↓	4.1	↓	↓
1.0			4.0		
1.1			3.9		
1.3			3.9		
3.0	-4 to 54	±4	[a]15-22	50	[a]$2.6\text{-}3.8\times10^6$
4.0	-4 to 15	±2	87	50	8.9×10^6
5.0	-4 to 54	±2	87	200	3.8×10^6

[a]For models tested at angles of attack greater than 32°.

Procedure

Aerodynamic forces and moments were measured with a conventional, six-component, strain-gage balance. Part of the balance system was inside the models and part protruded rearward to the sting-support system. The external portions of the balance were shrouded to prevent the direct action of the aerodynamic forces on the balance. Base pressures acting on the models were measured with a strain-gage pressure cell; however, these pressures were not used to correct the aerodynamic forces and moments. All results presented therefore include the effects of base drag and sting interference.

Accuracy

Estimated maximum uncertainties in the test results are as follows:

Angles	±0.2°
Mach numbers 0.6 to 1.3	±0.01
Mach numbers 3.0 to 5.0	±0.10
Force coefficients	±0.01
Moment coefficients	±0.005
Stability derivatives	±0.0005 per deg

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It should be noted that the control data were obtained with the largest model and, therefore, these incremental experimental results are in error by less than the above estimates.

RESULTS AND DISCUSSION

Presentation of Results

Nomenclature.- The first part of this investigation was concerned with determining the aerodynamic characteristics of the boattailed, half-cone body with vertical fins and canopy added. In the following presentation and discussion, this basic model will be referred to as the clean configuration; more explicitly, the term "clean" will imply the model configuration with elevons removed and with pitch and yaw flaps undeflected.

Individual control characteristics were obtained by testing separately the pitch flaps, yaw flaps, and elevons on the clean configuration. Incremental coefficients for the controls were obtained by comparison of the control data with data previously obtained for the clean configuration. For example, the normal-force increment due to an elevon was determined from the relation $\Delta C_{N_e} = (C_N)_{\substack{\text{with} \\ \text{elevon}}} - (C_N)_{\text{clean}}$.

Two particular control combinations were tested on the clean configuration to demonstrate typical trim aerodynamic characteristics at widely different model attitudes. The resulting model configurations will be referred to as (1) the configuration for small-angle trim (both elevons at -10° and both pitch flaps at 35°), and (2) the configuration for large-angle trim (both elevons at -40° and pitch flaps undeflected).

Presentation.- The longitudinal characteristics of the clean configuration are presented in figures 4 through 10, and of the trimmed configurations in figures 11 through 14. Data for transonic speeds are presented for angles of attack from -1° to +15°; data for supersonic speeds are

presented for angles of attack from -4° to $+16^\circ$ at Mach number 4.0 and from -4° to $+54^\circ$ at Mach numbers 3.0 and 5.0. Shadowgraphs of the flow around the trimmed configurations at a Mach number of 5.0 are shown in figure 15.

The lateral-directional characteristics of each model configuration tested are presented in table I; listed are the derivatives C_{y_β}, C_{n_β} and C_{l_β}, evaluated at zero sideslip angle. Sideslip angles for which the data were obtained were previously noted. Note that table I includes lateral-directional data for models with various controls.

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The control characteristics obtained from tests at zero sideslip angle are presented in tables II, III, and IV for pitch flaps, yaw flaps, and elevons, respectively. Note that these data are presented in incremental form. These characteristics were obtained at angles of attack to 16°. Data are given for the starboard yaw flap or elevon, and for pairs of pitch flaps.

Characteristics of Clean Configuration

Longitudinal stability.- Pitching-moment coefficients for the clean configuration may be seen in figure 4. The moment center assumed is 0.55 body length aft of the nose and 0.07 body length below the cone axis. For this moment center, the clean configuration was slightly unstable in pitch for Mach numbers from 0.6 to 1.3 (fig. 4(a)). For Mach numbers 3.0 and 5.0 the configuration was slightly unstable at angles of attack below about 30°, but was stable at larger angles of attack to 54° (fig. 4(b)). The increase in stability at large angles of attack was apparently due to the longitudinally curved undersurface. This point can be qualitatively discussed with the help of Newtonian impact theory.

Near zero angle of attack the afterportion of the undersurface is shielded in the Newtonian sense and, accordingly, the surface pressure of the shielded region approaches the free-stream pressure. The higher pressure on the portion of the undersurface forward of the moment center thus combines with the nose drag to produce a positive pitching moment. As the angle of attack is increased, the afterportion of the undersurface becomes completely unshielded at about 15° angle of attack and the local pressure coefficient increases approximately as $\sin^2(\alpha - 15)$. Because of this variation, the contribution of the aftersurface is not appreciable unless α is somewhat greater than 15°. For the present configuration the pressure acting on the aftersurface appears to become significant at about 30° angle of attack. At angles of attack somewhat greater than 30° the loading on the boattailed region, coupled with the larger area aft of the moment center, has an increasing effect which accounts for the increase in stability.

It is apparent from figure 4(b) that at Mach number 3.0 the clean configuration possessed some longitudinal stability at the trim angle of 45°. Further, only small control moments would be required to provide trim over a wide range of angles of attack. However, for stable trim conditions at angles of attack less than about 30°, an increment of longitudinal stability would have to be provided by the controls, or the moment center would have to be moved forward. The effects of controls in this regard will be discussed subsequently. It is of interest to consider the effects of a shift in the moment center on the longitudinal stability of the clean configuration. Illustrated in figure 16 are faired pitching-moment data for a moment center 10 percent of the body length ahead of the reference center given above. With this center the clean configuration was trimmed near zero angle of attack for Mach numbers from 3.0 to 5.0, and near maximum lift-drag ratio for Mach number 0.6. However, for the remaining test Mach numbers of 0.9, 1.0, 1.1, and 1.3, trim points with stable slopes were not attained in the test range of angles of attack.

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Lateral-directional stability.- Variations with angle of attack of the lateral- and directional-stability derivatives of the clean configuration were, in general, relatively small. This is illustrated for Mach number 5.0 in figure 17(a). In contrast, the variations with Mach number, shown in figure 17(b) for 7.2° angle of attack were large, especially in the transonic speed range. The unstable characteristics indicated in the data of figure 17(b) are representative of most of the data shown in table V; that is, all data for Mach number 1.0 and the data for 14° angle of attack, Mach number 0.9. At these test conditions the clean configuration was consistently unstable for small angles of sideslip, and was usually stable at sideslip angles larger than about 2°. The reason for this instability at small angles was not established. Typical data are shown in figure 18. These are the data from which the derivatives presented in figure 17(b) were obtained. Derivatives were not evaluated for the remaining data at these test conditions; but for reference purposes, all data showing similar characteristics are presented in table V.

The effect of the vertical fins on the lateral and directional stability was determined at Mach numbers 3.0, 4.0, and 5.0 only. Lateral-directional characteristics of the clean configuration without fins are presented in table I. As would be expected, the fins improved the directional stability. It is also interesting to note that the dihedral effect was essentially unchanged by removal of the fins.

Performance.- Maximum lift-drag ratios and lift coefficients at 10° angle of attack (which corresponds approximately with maximum lift-drag ratio) are shown in figure 19 for the clean configuration and for the modified half-cone of reference 8. Characteristics at transonic speeds for the modified half-cone were obtained during the present investigation and are presented in the appendix. As shown in figure 19, the boattailing had little effect on the lift and drag characteristics at supersonic speeds

and on the lift at transonic speeds. However, for Mach numbers less than 1.0 the boattailed model had substantially greater lift-drag ratios than the larger based model.

Also shown in figure 19 is the maximum lift-drag ratio obtained in reference 11 for the clean configuration at a Mach number of 0.6. The present data indicate a maximum lift-drag ratio about 10 percent lower than that of reference 11. This difference is due to larger drag in the present test at angles of attack between about 5° and 12° (C_L = 0.28 to 0.45). The higher drag is attributed to viscous effects associated with the low Reynolds number of the present test (about 0.6 million as compared to 5 million for ref. 11).

It should also be noted that the performance at transonic speeds may have been affected by sting interference. From the results of reference 15, it is indicated that the measured maximum lift-drag ratio at Mach number 1.0 may be about 7 percent high as a result of this effect. Sting-interference effects therein tended to decrease at higher or lower Mach numbers; for this reason results at Mach number 0.6 and at Mach numbers of 3.0 or greater are believed to be unaffected by sting interference.

Control Characteristics

Pitch flaps.- The characteristics of the pitch flaps are illustrated in figure 20, where representative data from table II are shown. The variations of ΔC_m with angle of attack indicate that the pitch flaps generally maintained or, for some conditions, increased the stability of the model (i.e., increased $-C_{m_\alpha}$). It is also indicated that the effectiveness of the pitch flaps decreased with increasing Mach numbers above 1.0. In spite of this decrease, however, the data for a Mach number of 5.0 indicate that a flap deflection of about 45° provided a moment contribution sufficient to trim the clean configuration at about -1° angle of attack (C_L = 0.05).

Yaw flaps.- Representative results for the yaw flaps, taken from table III, are shown in figure 21. The yaw flaps appeared adequate to trim the configuration at small angles of sideslip. For example, for a Mach number of 5.0 the yawing moment for the clean configuration at 2° sideslip was about 0.0014 (fig. 17), which is less than 20 percent of the moment increment due to the 30° yaw flap (fig. 21(a)). Rolling moments due to yaw flap deflections were small at all Mach numbers (table III).

Axial-force increments due to yaw flap deflections (fig. 21(b)) provided significant decreases in lift-drag ratio. For example, with two yaw flaps deflected 30° the maximum lift-drag ratio of the clean configuration at supersonic speeds was reduced from about 1.3 to 1.1. It should

also be noted that a decrease in axial force occurred at Mach number 1.0 with increased deflection angle from 20° to 30°. This effect was due, at least in part, to a corresponding increase in base pressure.

Elevons.- Typical rolling-moment increments due to the elevons are shown in figure 22. In this presentation the ordinate ($\Delta C_l/\cos \delta_e$) represents the rolling moment about an axis in the plane of the elevon, and the abscissa ($\alpha + \delta_e$) represents the angle of attack of the elevon with respect to the free stream. When plotted in this manner, the characteristics of the elevons estimated with Newtonian impact theory are represented by a single curve.

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The ability of the elevons to produce rolling moments can be illustrated by considering a differential deflection of right and left elevons from the trimmed setting. Data in figure 22 for a Mach number of 5.0 and an angle of attack of 7° indicate that a 40° differential deflection (right elevon at 10° and left elevon at -30°) produced a rolling-moment coefficient of -0.013. This moment can be compared with a value of 0.0036 for the clean configuration at -2° sideslip (fig. 17). Yawing moments due to this 40° differential deflection were obtained from the data of table IV, and are shown in figure 23. The yawing moments shown are small at a Mach number of 5, but are relatively large at transonic Mach numbers. This coupling is adverse in the sense that an attempt to counteract a positive roll rate results in a positive yawing moment. While the control cross-coupling appears to be small at supersonic speeds in the example cited above, such effects can be expected to be more pronounced at larger angles of attack. This can be visualized by considering an extreme case with the configuration at 90° angle of attack and the elevons at -90° deflection. Clearly, perturbations of the elevons about this position would primarily result in yawing moments.

Interactions between controls.- Determination of control interactions was not a primary objective of the present test. However, some data were obtained which allow a cursory examination of these effects. In particular, the data obtained with the pitch flaps and elevons individually can be compared with the data for the trimmed configurations on which the controls were used in combination. To illustrate such effects, pitching moments were computed for the configuration for small-angle trim, for Mach numbers from 0.6 to 1.3, based on the data obtained for the individual controls (fig. 4 and tables II and IV). Results of these calculations are shown in figure 11(a) as shaded symbols. In most instances control data in combination with the data for the clean configuration provided reasonably accurate estimates of the pitching moments of the trimmed configuration.

It is observed that because of the proximity of the yaw flaps to the elevons, interactions between them would be expected to be larger than those between the pitch flaps and the elevons; however, such interactions were not investigated.

Characteristics of Trimmed Configurations

It was indicated in a previous section of this paper that two trimmed configurations were tested to illustrate typical trim characteristics. These are the configuration for small-angle trim (elevons at -10° and pitch flaps at 35°) and the configuration for large-angle trim (elevons at -40° and pitch flaps undeflected). Control settings which characterize these configurations were selected with the use of data obtained with the clean configuration in combination with individual controls. The configuration for small-angle trim was intended to trim near maximum lift-drag ratio for Mach numbers of 3.0 to 5.0. The configuration for large-angle trim was intended to trim near maximum lift for Mach numbers from 3.0 to 5.0. Static stability and performance characteristics of these two trimmed configurations, taken from figures 11, 12, and 13, and table I, are summarized in figures 24 and 25. It should be noted that some extrapolation of the test results was necessary to obtain these summarized results for Mach numbers 1.0 and 1.3. At these Mach numbers the trim points appear to be 2° to 3° below the range of test angles of attack. The results presented in figures 24 and 25 were obtained, for these cases, with the aid of a short and linear extrapolation of the pitching-moment curves (fig. 11(a)).

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Stability.- As shown in figure 24, both trimmed configurations were longitudinally stable at supersonic speeds. At transonic speeds longitudinal data are shown only for the configuration for small-angle trim and show this configuration to be longitudinally stable at transonic speeds.

Lateral-directional data for transonic speeds were not obtained for either of the trimmed configurations. However, data were obtained for the clean configuration in combination with various individual controls and are presented in tables I and V. For comparison with the characteristics of the trimmed configurations, lateral-directional characteristics of the clean configuration are also indicated in figure 24. It is observed that the trimmed configurations were generally somewhat more stable than the clean configuration at supersonic speeds. Also, it should be noted that the data of table V indicate that the lateral-directional instability near Mach number 1.0 previously noted for the clean configuration persists when the individual controls are added.

Performance.- Trim lift coefficients and lift-drag ratios are shown in figure 25. At supersonic speeds the configuration for small-angle trim developed trim lift-drag ratios within 5 percent of the maximum lift-drag ratio of the configuration. At supersonic speeds the configuration for large-angle trim developed trim lift coefficients within 5 percent of the maximum lift coefficient of the configuration. For subsonic and transonic speeds the trim lift-drag ratios from the present tests were somewhat below the maximum values (cf. clean configuration, fig. 19). For comparison, data from reference 11 are shown for a similar configuration

representative of the landing condition. Here the elevons were at -10°, as for the small-angle trim condition of the present tests, but the pitch flaps were retracted and a trailing-edge flap was added.

In summary, at supersonic speeds the present configuration developed lift-drag ratios almost equal to those of the modified 13° half-cone from which it was derived and, in addition, provided for trim to nearly maximum lift. The trim lift-drag ratio of 1.2 is equivalent to about 900 nautical miles lateral range for entry from a near earth satellite orbit (ref. 7).

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SUMMARY OF RESULTS

The aerodynamic characteristics of an atmosphere-entry configuration developing lift-drag ratios near 1.2 at supersonic speeds were experimentally investigated at Mach numbers from 0.6 to 5.0. The basic configuration was one-half of a 13° half-angle cone with a blunted nose and a boattailed afterportion to which were added a canopy and a pair of vertical stabilizing fins. Controls consisting of elevons, pitch flaps, and yaw flaps were also tested with the basic configuration. Moments were referred to a point 0.55 body length aft of the nose and 0.07 body length below the cone axis.

The basic configuration without controls was longitudinally stable near maximum lift coefficient at supersonic speeds, and was slightly unstable at lower lift coefficients over the entire range of test Mach numbers. For most of the test Mach numbers, subsonic and supersonic, the configuration was directionally and laterally stable. Near a Mach number of 1.0, directional and lateral instabilities were observed at small angles of sideslip; however, the moment curves were nonlinear and stable characteristics prevailed at sideslip angles greater than about ±2°.

The configuration complete with controls was tested with two different combinations of elevon and pitch flap angles at supersonic speeds to demonstrate trim characteristics at widely different attitudes. One of these configurations resulted in a trim lift-drag ratio of 1.2 at a Mach number of 5.0, which was within 5 percent of the maximum lift-drag ratio. The second configuration resulted in a trim lift coefficient of 0.45 at a Mach number of 5.0, which was within 5 percent of the maximum lift coefficient. In general, a combination of elevons and pitch flaps appeared adequate to provide trim at positive lift coefficients with longitudinal stability throughout the Mach number range of the tests.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., April 26, 1961

APPENDIX

TRANSONIC AERODYNAMIC CHARACTERISTICS OF A MODIFIED 13° HALF-CONE

Preliminary to the testing of the boattailed configuration decribed in the body of this paper, a blunted 13° half-cone was tested at supersonic speeds (ref. 8) and at subsonic speeds (refs. 9 and 10). Also, the characteristics at supersonic speeds of a modified version of this half-cone were investigated in reference 8. During the present investigation the modified 13° half-cone was tested at transonic speeds in the Ames 2- by 2-Foot Wind Tunnel, and the results of these tests are presented herein. Experimental technique and test conditions were identical with those described in the body of this paper. Model geometry and photographs are shown in figures 26 and 27. Results in standard coefficient form are presented in figure 28 and table VI.

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TABLE I.- LATERAL-DIRECTIONAL DERIVATIVES FOR ALL MODEL CONFIGURATIONS TESTED

Configuration	α, deg	C_{y_β}, per deg							C_{n_β}, per deg							C_{l_β}, per deg						
		M=0.6	M=0.9	M=1.1	M=1.3	M=3.0	M=4.0	M=5.0	M=0.6	M=0.9	M=1.1	M=1.3	M=3.0	M=4.0	M=5.0	M=0.6	M=0.9	M=1.1	M=1.3	M=3.0	M=4.0	M=5.0
	0.1	-0.0134	-0.0148	-0.0211	-0.0170	-0.0142	-0.0125	-0.0105	0.0018	0.0018	0.0063	0.0033	0.0013	0.0009	0.0006	-0.0053	-0.0044	-0.0058	-0.0038	-0.0022	-0.0018	-0.0015
	7.2	-.0160	-.0140	-.0194	-.0180	-.0152	-.0140	-.0127	.0028	.0000	.0044	.0025	.0012	.0010	.0007	-.0067	-.0044	-.0053	-.0042	-.0024	-.0021	-.0018
Clean	14.4	-.0178	- - -	-.0211	-.0240	-.0180	-.0156	-.0151	.0016	- - -	.0018	.0050	.0015	.0009	.0005	-.0070	- - -	-.0053	-.0044	-.0027	-.0022	-.0022
	21.3	- - -	- - -	- - -	- - -	-.0185	- - -	-.0155	- - -	- - -	- - -	- - -	.0015	- - -	.0010	- - -	- - -	- - -	- - -	-.0027	- - -	-.0028
$\delta_p=0^\circ$, $\delta_y=0^\circ$	28.3	- - -	- - -	- - -	- - -	-.0195	- - -	-.0175	- - -	- - -	- - -	- - -	.0013	- - -	.0015	- - -	- - -	- - -	- - -	-.0029	- - -	-.0026
elevons off	36.2	- - -	- - -	- - -	- - -	-.0210	- - -	-.0189	- - -	- - -	- - -	- - -	.0010	- - -	.0010	- - -	- - -	- - -	- - -	-.0024	- - -	-.0031
	43.2	- - -	- - -	- - -	- - -	-.0219	- - -	-.0195	- - -	- - -	- - -	- - -	.0015	- - -	.0000	- - -	- - -	- - -	- - -	-.0035	- - -	-.0027
	50.2	- - -	- - -	- - -	- - -	-.0219	- - -	-.0194	- - -	- - -	- - -	- - -	.0026	- - -	.0005	- - -	- - -	- - -	- - -	-.0037	- - -	-.0029
Clean; one	.1	-.0134	-.0148	-.0225	-.0187	- - -	- - -	- - -	.0025	.0017	.0092	.0046	- - -	- - -	- - -	-.0059	-.0045	-.0066	-.0045	- - -	- - -	- - -
elevon;	7.2	-.0159	-.0145	-.0214	-.0190	-.0159	-.0145	-.0136	.0032	.0000	.0060	.0032	.0017	.0017	.0015	-.0070	-.0045	-.0056	-.0047	-.0031	-.0027	-.0026
$\delta_e=10^\circ$	14.4	-.0160	- - -	-.0224	-.0232	-.0184	-.0177	-.0163	.0007	- - -	.0032	.0060	.0020	.0020	.0015	-.0064	- - -	-.0050	-.0049	-.0034	-.0029	-.0030
Clean; one	.1	-.0134	-.0148	-.0232	-.0178	- - -	- - -	- - -	.0022	.0016	.0080	.0044	- - -	- - -	- - -	-.0055	-.0046	-.0062	-.0043	- - -	- - -	- - -
elevon;	7.2	-.0159	-.0148	-.0180	-.0223	-.0154	-.0140	-.0134	.0028	.0006	.0043	.0026	.0015	.0013	.0010	-.0070	-.0056	-.0060	-.0046	-.0026	-.0026	-.0020
$\delta_e=-10^\circ$	14.4	-.0178	- - -	-.0216	-.0185	-.0181	-.0167	-.0152	.0014	- - -	.0028	.0034	.0015	.0016	.0009	-.0074	.0188	-.0054	-.0048	-.0030	-.0024	-.0025
Clean; one	7.2	- - -	- - -	- - -	- - -	-.0154	-.0140	-.0134	- - -	- - -	- - -	- - -	.0013	.0012	.0012	- - -	- - -	- - -	- - -	-.0024	-.0019	-.0015
elevon; $\delta_e=-20^\circ$	36.0	- - -	- - -	- - -	- - -	-.0212	- - -	-.0190	- - -	- - -	- - -	- - -	.0015	- - -	.0018	- - -	- - -	- - -	- - -	-.0034	- - -	-.0043
Clean; one	.1	-.0140	-.0140	-.0232	-.0180	- - -	- - -	- - -	.0025	.0017	.0077	.0044	- - -	- - -	- - -	-.0054	-.0038	-.0057	-.0041	- - -	- - -	- - -
elevon;	7.2	-.0158	-.0140	-.0170	-.0180	-.0154	-.0140	-.0132	.0032	.0000	.0023	.0033	.0015	.0013	.0013	-.0068	-.0046	-.0052	-.0043	-.0024	-.0018	-.0014
$\delta_e=-30^\circ$	14.4	-.0176	- - -	-.0216	-.0237	-.0184	-.0170	-.0152	.0013	- - -	.0032	.0100	.0017	.0016	.0011	-.0073	.0163	-.0055	-.0048	-.0026	-.0021	-.0020
Large-angle trim;	36.0	- - -	- - -	- - -	- - -	-.0202	- - -	-.0195	- - -	- - -	- - -	- - -	.0013	- - -	.0024	- - -	- - -	- - -	- - -	-.0023	- - -	-.0032
$\delta_e=-40^\circ$(both)	43.2	- - -	- - -	- - -	- - -	-.0230	- - -	-.0199	- - -	- - -	- - -	- - -	.0023	- - -	.0000	- - -	- - -	- - -	- - -	-.0039	- - -	-.0039
$\delta_p=0$	50.0	- - -	- - -	- - -	- - -	-.0216	- - -	-.0200	- - -	- - -	- - -	- - -	.0026	- - -	.0021	- - -	- - -	- - -	- - -	-.0037	- - -	-.0039
Clean; one	.1	-.0136	-.0150	-.0213	-.0183	- - -	- - -	- - -	.0024	.0020	.0078	.0048	- - -	- - -	- - -	-.0052	-.0041	-.0055	-.0041	- - -	- - -	- - -
yaw flap	7.2	-.0156	-.0147	-.0202	-.0185	- - -	- - -	- - -	.0028	.0004	.0054	.0032	- - -	- - -	- - -	-.0064	-.0046	-.0056	-.0043	- - -	- - -	- - -
$\delta_y=20^\circ$	14.4	-.0170	-.0084	-.0225	-.0209	-.0187	-.0175	-.0173	.0016	-.0092	.0060	.0028	.0018	.0016	.0007	-.0068	.0154	-.0048	-.0043	-.0027	-.0023	-.0023
	36.0	- - -	- - -	- - -	- - -	-.0208	- - -	-.0188	- - -	- - -	- - -	- - -	.0016	- - -	.0010	- - -	- - -	- - -	- - -	-.0031	- - -	-.0028
Clean; one	.1	-.0134	-.0150	-.0218	-.0172	- - -	- - -	- - -	.0024	.0012	.0076	.0042	- - -	- - -	- - -	-.0051	-.0036	-.0048	-.0036	- - -	- - -	- - -
yaw flap	7.2	-.0152	-.0145	-.0206	-.0188	-.0163	-.0152	-.0148	.0028	.0000	.0052	.0034	.0021	.0024	.0030	- 0065	-.0044	-.0056	-.0043	-.0025	-.0021	-.0019
$\delta_y=30^\circ$	14.4	-.0173	-.0076	-.0222	-.0225	-.0184	-.0177	-.0162	.0012	-.0144	.0041	.0030	.0022	.0021	.0018	-.0068	.0128	-.0050	-.0044	-.0027	-.0025	-.0023
	36.0	- - -	- - -	- - -	- - -	-.0219	- - -	-.0188	- - -	- - -	- - -	- - -	.0016	- - -	.0010	- - -	- - -	- - -	- - -	-.0033	- - -	-.0030
Small-angle trim;	.1	- - -	- - -	- - -	- - -	-.0135	-.0122	-.0120	- - -	- - -	- - -	- - -	.0017	.0017	.0020	- - -	- - -	- - -	- - -	-.0023	-.0020	-.0016
$\delta_e=-10^\circ$(both)	7.2	- - -	- - -	- - -	- - -	-.0160	-.0143	-.0143	- - -	- - -	- - -	- - -	.0020	.0019	.0024	- - -	- - -	- - -	- - -	-.0027	-.0022	-.0021
$\delta_p=35^\circ$(both)	14.4	- - -	- - -	- - -	- - -	-.0185	-.0165	-.0166	- - -	- - -	- - -	- - -	.0022	.0020	.0020	- - -	- - -	- - -	- - -	-.0031	-.0026	-.0026
Clean; both ver-	7.2	- - -	- - -	- - -	- - -	-.0143	-.0130	-.0120	- - -	- - -	- - -	- - -	.0000	.0000	.0000	- - -	- - -	- - -	- - -	-.0022	-.0018	-.0018
tical fins off	14.4	- - -	- - -	- - -	- - -	-.0160	-.0160	- - -	- - -	- - -	- - -	- - -	.0004	.0005	- - -	- - -	- - -	- - -	- - -	-.0024	-.0024	- - -

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TABLE II.- INCREMENTAL FORCE AND MOMENT COEFFICIENTS DUE TO BOTH PITCH FLAPS

Pitch flap deflection	α, deg	M=0.6	M=0.9	M=1.0	M=1.1	M=1.3	M=3.0	M=4.0	M=5.0
		ΔC_m							
δ_p=15°	-4.0	- - -	- - -	- - -	- - -	- - -	-0.001	-0.001	0.000
	0.1	-0.013	-0.003	-0.002	-0.007	-0.006	-.001	-.001	.000
	4.1	-.014	-.007	-.011	-.009	-.006	.000	.000	-.001
	8.2	-.019	-.012	-.013	-.008	-.009	- - -	- - -	.000
	12.3	-.016	-.018	-.010	-.013	-.009	- - -	- - -	- - -
	15.4	-.017	-.025	-.011	-.015	-.011	- - -	- - -	- - -
δ_p=35°	-4.0	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	0.1	-.031	-.024	-.017	-.019	-.016	- - -	- - -	- - -
	4.1	-.033	-.034	-.037	-.023	-.021	- - -	- - -	- - -
	8.2	-.037	-.047	-.044	-.026	-.023	- - -	- - -	- - -
	12.3	-.036	-.071	-.057	-.034	-.023	- - -	- - -	- - -
	15.4	-.038	-.065	-.048	-.035	-.024	- - -	- - -	- - -
δ_p=45°	-4.0	- - -	- - -	- - -	- - -	- - -	-.009	-.006	-.004
	0.1	- - -	- - -	- - -	- - -	- - -	-.011	-.008	-.006
	4.1	- - -	- - -	- - -	- - -	- - -	-.013	-.009	-.009
	8.2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	-.022	-.023	-.020
	15.4	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	-.026	- - -	-.023
		ΔC_N							
δ_p=15°	-4.0	- - -	- - -	- - -	- - -	- - -	.004	.002	.001
	0.1	.048	.010	.005	.021	.013	.004	.004	.002
	4.1	.049	.020	.040	.025	.016	.007	.001	.004
	8.2	.056	.026	.032	.011	.019	- - -	- - -	.005
	12.3	.050	.050	.026	.029	.026	- - -	- - -	- - -
	15.4	.040	.064	.019	.022	.028	- - -	- - -	- - -
δ_p=35°	-4.0	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	0.1	.115	.078	.041	.046	.042	- - -	- - -	- - -
	4.1	.124	.100	.108	.060	.053	- - -	- - -	- - -
	8.2	.140	.148	.122	.059	.061	- - -	- - -	- - -
	12.3	.130	.230	.160	.090	.078	- - -	- - -	- - -
	15.4	.125	.200	.125	.087	.070	- - -	- - -	- - -
δ_p=45°	-4.0	- - -	- - -	- - -	- - -	- - -	.021	.015	.010
	0.1	- - -	- - -	- - -	- - -	- - -	.024	.020	.015
	4.1	- - -	- - -	- - -	- - -	- - -	.029	.022	.019
	8.2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	.038	.039	.041
	15.4	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	.048	- - -	.046
		ΔC_A							
δ_p=15°	-4.0	- - -	- - -	- - -	- - -	- - -	.001	.000	.000
	0.1	.000	.000	.006	.000	-.003	.000	.000	.000
	4.1	.005	-.002	.013	-.006	-.003	.001	.001	.002
	8.2	.000	.005	.009	-.004	.001	- - -	- - -	.003
	12.3	.008	.000	-.005	.000	-.001	- - -	- - -	- - -
	15.4	.005	.007	-.007	-.006	.001	- - -	- - -	- - -
δ_p=35°	-4.0	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	0.1	.035	.035	.035	.030	.024	- - -	- - -	- - -
	4.1	.040	.036	.035	.020	.024	- - -	- - -	- - -
	8.2	.042	.048	.051	.023	.025	- - -	- - -	- - -
	12.3	.042	.053	.057	.031	.028	- - -	- - -	- - -
	15.4	.042	.058	.044	.033	.026	- - -	- - -	- - -
δ_p=45°	-4.0	- - -	- - -	- - -	- - -	- - -	.009	.006	.004
	0.1	- - -	- - -	- - -	- - -	- - -	.011	.009	.007
	4.1	- - -	- - -	- - -	- - -	- - -	.015	.012	.010
	8.2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	.023	.021	.024
	15.4	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	.028	- - -	.030

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TABLE III.- INCREMENTAL FORCE AND MOMENT COEFFICIENTS DUE TO A STARBOARD YAW FLAP

Control deflection	α, deg	M=0.6	M=0.9	M=1.0	M=1.1	M=1.3	M=3.0	M=4.0	M=5.0
		ΔC_A							
δ_y=20°	0.1	0.024	0.023	0.024	0.027	0.018	0.005	0.005	0.005
	4.1	.023	.018	.020	.015	.015	- - -	- - -	- - -
	7.2	.022	.014	.009	.014	.013	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	.005
	10.3	.020	.011	- - -	.013	.012	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	.002	.002	.003
	14.4	.018	.021	-.002	.007	.011	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	.003	- - -	.004
δ_y=30°	.1	.036	.033	-.001	.045	.027	- - -	- - -	- - -
	4.1	.035	.028	.004	.027	.025	.011	.008	.010
	7.2	.029	.030	.005	.024	.025	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	.011	.008	.010
	10.3	.028	.011	-.006	.023	.023	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	.005	.007	.009
	14.4	.026	.016	-.015	.016	.021	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	.005	- - -	.010
		ΔC_n							
δ_y=20°	.1	.019	.044	.016	.020	.016	- - -	- - -	- - -
	4.1	.017	.021	.023	.020	.015	.004	.003	.004
	7.2	.016	.020	.029	.017	.015	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	.004
	10.3	.014	.038	- - -	.017	.009	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	.007	.005	.005
	14.4	.015	.044	.033	.022	.006	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	.006	- - -	.005
δ_y=30°	.1	.032	.044	.033	.033	.030	- - -	- - -	- - -
	4.1	.030	.042	.043	.030	.028	.015	.013	.011
	7.2	.029	.045	.040	.030	.028	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	.013	.013	.012
	10.3	.024	.042	.033	.036	.020	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	.015	.013	.013
	14.4	.026	.053	.040	.035	.012	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	.014	- - -	.014
		ΔC_y							
δ_y=20°	.1	-.022	-.036	-.020	-.020	-.016	- - -	- - -	- - -
	4.1	-.017	-.024	-.029	-.019	-.013	-.003	-.003	-.003
	7.2	-.019	-.024	-.027	-.016	-.015	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	-.004
	10.3	-.016	-.035	- - -	-.016	-.013	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	-.007	-.006	-.006
	14.4	-.017	-.039	-.028	-.016	-.015	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	-.006	- - -	-.006
δ_y=30°	.1	-.034	-.047	-.039	-.029	-.027	- - -	- - -	- - -
	4.1	-.032	-.045	-.045	-.028	-.023	-.010	-.009	-.009
	7.2	-.029	-.045	-.040	-.027	-.024	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	-.010	-.009	-.010
	10.3	-.025	-.045	-.034	-.029	-.023	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	-.013	-.011	-.012
	14.4	-.026	-.056	-.036	-.028	-.023	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	-.011	- - -	-.013
		ΔC_l							
δ_y=20°	.1	-.004	-.002	-.001	.000	-.001	- - -	- - -	- - -
	4.1	-.004	-.001	-.008	.000	-.001	.000	.000	.000
	7.2	-.004	-.002	-.005	-.001	-.001	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	.000
	10.3	-.003	- - -	- - -	-.001	-.001	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	.000	.000	.000
	14.4	-.004	-.008	-.008	-.001	-.001	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	-.001	- - -	.000
δ_y=30°	.1	-.007	-.006	-.004	.000	-.001	- - -	- - -	- - -
	4.1	-.007	-.005	-.013	-.001	-.001	-.001	-.001	-.001
	7.2	-.006	-.004	-.007	-.001	-.001	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	-.001	-.001	-.001
	10.3	-.005	-.001	-.001	-.001	-.001	- - -	- - -	.000
	12.3	- - -	- - -	- - -	- - -	- - -	.000	-.001	- - -
	14.4	-.005	-.008	-.008	-.002	-.001	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	.000	- - -	.000

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TABLE IV.- INCREMENTAL FORCE AND MOMENT COEFFICIENTS DUE TO A STARBOARD ELEVON

Control deflection	α, deg	M=0.6	M=0.9	M=1.0	M=1.1	M=1.3	M=3.0	M=4.0	M=5.0	M=0.6	M=0.9	M=1.0	M=1.1	M=1.3	M=3.0	M=4.0	M=5.0	M=0.6	M=0.9	M=1.0	M=1.1	M=1.3	M=3.0	M=4.0	M=5.0
		ΔC_m								ΔC_A								ΔC_Y							
δ_e=10°	0.1	-0.012	-0.008	-0.012	-0.012	-0.011	- - -	- - -	- - -	0.007	0.008	-0.007	0.026	0.015	- - -	- - -	- - -	-0.010	-0.022	-0.024	-0.024	-0.020	- - -	- - -	- - -
	4.1	-.016	-.012	-.021	-.013	-.014	-0.002	-0.002	-0.003	.007	.010	.010	.012	.010	0.016	0.011	0.012	-.015	-.022	-.041	-.031	-.025	-0.009	-0.006	-0.007
	7.2	-.016	-.004	-.010	-.016	-.015	- - -	- - -	- - -	.013	.012	.002	.013	.014	- - -	- - -	- - -	-.018	-.031	-.035	-.038	-.028	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	-.003	-.003	-.004	- - -	- - -	- - -	- - -	- - -	.013	.000	.000	- - -	- - -	- - -	- - -	- - -	-.010	-.008	-.009
	10.3	-.018	-.007	-.002	-.017	-.014	- - -	- - -	- - -	.010	.000	-.013	.009	.014	- - -	- - -	- - -	-.024	-.035	-.025	-.038	-.031	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	-.003	-.005	-.003	- - -	- - -	- - -	- - -	- - -	.000	.000	.021	- - -	- - -	- - -	- - -	- - -	-.009	-.010	-.009
	14.4	-.017	-.006	-.008	-.019	-.013	- - -	- - -	- - -	.007	.012	- - -	.009	.015	- - -	- - -	- - -	-.027	-.047	-.023	-.046	-.039	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	-.005	- - -	-.003	- - -	- - -	- - -	- - -	- - -	.000	- - -	.021	- - -	- - -	- - -	- - -	- - -	-.013	- - -	-.011
δ_e=-10°	.1	.006	.008	.007	.006	.003	- - -	- - -	- - -	.007	.008	.024	.015	.012	- - -	- - -	- - -	.003	.008	-.004	-.002	-.004	- - -	- - -	- - -
	4.1	.000	.004	-.004	-.002	-.001	.001	.001	.001	.000	.005	.011	.007	.005	.006	.000	.002	-.002	.000	-.009	-.009	-.007	-.004	-.004	-.004
	7.2	-.002	-.009	-.006	-.002	-.004	- - -	- - -	- - -	.007	.005	.009	.002	.005	- - -	- - -	- - -	-.004	-.010	-.010	-.014	-.011	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	.001	.000	.001	- - -	- - -	- - -	- - -	- - -	.004	.000	.000	- - -	- - -	- - -	- - -	- - -	-.005	-.004	-.005
	10.3	-.008	-.008	-.004	-.009	-.005	- - -	- - -	- - -	.000	-.008	-.005	-.002	.000	- - -	- - -	- - -	-.007	-.003	-.017	-.018	-.014	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	-.002	-.001	-.002	- - -	- - -	- - -	- - -	- - -	.000	.000	.000	- - -	- - -	- - -	- - -	- - -	-.007	-.005	-.006
	14.4	-.005	-.018	-.002	-.014	-.008	- - -	- - -	- - -	-.005	.005	- - -	-.009	-.004	- - -	- - -	- - -	-.014	.003	-.010	-.018	-.012	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	-.002	- - -	-.002	- - -	- - -	- - -	- - -	- - -	.000	- - -	.000	- - -	- - -	- - -	- - -	- - -	- - -	- - -	-.006
δ_e=-20°	4.1	- - -	- - -	- - -	- - -	- - -	.002	.002	.001	- - -	- - -	- - -	- - -	- - -	.007	.005	.006	- - -	- - -	- - -	- - -	- - -	-.004	-.005	-.005
	8.2	- - -	- - -	- - -	- - -	- - -	.001	.001	.001	- - -	- - -	- - -	- - -	- - -	.006	.000	.003	- - -	- - -	- - -	- - -	- - -	-.003	-.004	-.005
δ_e=-30°	.1	.016	.020	.027	.022	.017	- - -	- - -	- - -	.022	.036	.042	.037	.031	- - -	- - -	- - -	.008	-.001	-.005	.005	.000	- - -	- - -	- - -
	4.1	.014	.018	.012	.018	.013	.004	.004	.003	.020	.025	.042	.022	.021	.015	.011	.011	.008	.007	-.007	.004	-.001	-.005	-.005	-.006
	7.2	.013	.014	.011	.015	.012	- - -	- - -	- - -	.025	.025	.036	.021	.024	- - -	- - -	- - -	.007	.008	.007	.002	-.001	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	.003	.002	.002	- - -	- - -	- - -	- - -	- - -	.009	.007	.011	- - -	- - -	- - -	- - -	- - -	-.005	-.004	-.005
	10.3	.009	.007	.010	.007	.007	- - -	- - -	- - -	.022	.010	.022	.019	.011	- - -	- - -	- - -	.003	.010	.001	-.001	-.001	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	.001	.000	.001	- - -	- - -	- - -	- - -	- - -	.002	.004	.007	- - -	- - -	- - -	- - -	- - -	-.004	-.003	-.004
	14.4	.010	-.024	.002	-.002	.003	- - -	- - -	- - -	.010	.018	- - -	.009	.012	- - -	- - -	- - -	.000	.022	.004	.002	.002	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	.001	- - -	.001	- - -	- - -	- - -	- - -	- - -	.002	- - -	.008	- - -	- - -	- - -	- - -	- - -	-.004	- - -	-.004
		ΔC_N								ΔC_n								ΔC_l							
δ_e=10°	.1	.043	.015	.038	.036	.036	- - -	- - -	- - -	.008	.020	.017	.023	.020	- - -	- - -	- - -	-.016	-.019	-.023	-.022	-.019	- - -	- - -	- - -
	4.1	.045	.024	.064	.045	.049	.018	.013	.014	.010	.017	.031	.036	.023	.011	.009	.008	-.022	-.019	-.028	-.026	-.024	-.011	-.009	-.008
	7.2	.045	.010	.024	.044	.050	- - -	- - -	- - -	.012	.022	.035	.045	.028	- - -	- - -	- - -	-.024	-.019	-.015	-.028	-.027	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	.023	.018	.017	- - -	- - -	- - -	- - -	- - -	.012	.010	.009	- - -	- - -	- - -	- - -	- - -	-.013	-.010	-.009
	10.3	.035	-.010	.004	.050	.052	- - -	- - -	- - -	.015	.024	.018	.032	.023	- - -	- - -	- - -	-.022	-.018	-.007	-.028	-.029	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	.016	.022	.019	- - -	- - -	- - -	- - -	- - -	.013	.012	.009	- - -	- - -	- - -	- - -	- - -	-.015	-.012	-.011
	14.4	.013	.056	.010	.053	.059	- - -	- - -	- - -	.016	.037	.028	.045	.026	- - -	- - -	- - -	-.023	-.021	.000	-.031	-.031	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	.022	- - -	.018	- - -	- - -	- - -	- - -	- - -	.015	- - -	.012	- - -	- - -	- - -	- - -	- - -	-.017	- - -	-.014
δ_e=-10°	.1	-.010	-.032	-.015	-.006	.000	- - -	- - -	- - -	.000	-.012	.012	.007	.008	- - -	- - -	- - -	.006	.007	.007	.006	.004	- - -	- - -	- - -
	4.1	.000	-.009	.022	.012	.012	.000	-.003	-.001	.002	.000	.012	.010	.009	.006	.006	.005	.001	.002	.000	-.002	-.003	.000	.000	.000
	7.2	.011	.010	.024	.000	.017	- - -	- - -	- - -	.003	.007	.006	.013	.007	- - -	- - -	- - -	-.004	-.006	-.007	-.009	-.008	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	.001	.004	.002	- - -	- - -	- - -	- - -	- - -	.005	.005	.005	- - -	- - -	- - -	- - -	- - -	-.003	-.002	-.002
	10.3	.016	.014	.013	.028	.021	- - -	- - -	- - -	.003	-.003	.012	.013	.017	- - -	- - -	- - -	-.009	-.004	-.013	-.014	-.012	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	.001	.005	.010	- - -	- - -	- - -	- - -	- - -	.006	.005	.005	- - -	- - -	- - -	- - -	- - -	-.005	-.004	-.003
	14.4	.027	.056	-.005	.039	.032	- - -	- - -	- - -	.005	-.006	-.009	.008	.017	- - -	- - -	- - -	-.016	.003	-.012	-.021	-.017	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	.003	- - -	.006	- - -	- - -	- - -	- - -	- - -	.006	- - -	.007	- - -	- - -	- - -	- - -	- - -	-.006	- - -	-.004
δ_e=-20°	4.1	- - -	- - -	- - -	- - -	- - -	-.008	-.008	-.004	- - -	- - -	- - -	- - -	- - -	.009	.008	.006	- - -	- - -	- - -	- - -	- - -	.004	.003	.002
	8.2	- - -	- - -	- - -	- - -	- - -	-.005	-.010	-.006	- - -	- - -	- - -	- - -	- - -	.007	.007	.006	- - -	- - -	- - -	- - -	- - -	.000	.003	.005
δ_e=-30°	.1	-.038	-.055	-.062	-.047	-.033	- - -	- - -	- - -	.003	.012	.013	.010	.014	- - -	- - -	- - -	.017	.016	.025	.023	.018	- - -	- - -	- - -
	4.1	-.035	-.052	-.017	-.030	-.025	-.012	-.014	-.011	.002	.001	.011	.009	.010	.010	.011	.011	.015	.016	.022	.018	.014	.007	.006	.006
	7.2	-.025	-.038	-.020	-.033	-.018	- - -	- - -	- - -	.004	.003	.005	.004	.009	- - -	- - -	- - -	.013	.013	.017	.012	.011	- - -	- - -	- - -
	8.2	- - -	- - -	- - -	- - -	- - -	-.005	-.005	-.006	- - -	- - -	- - -	- - -	- - -	.009	.008	.008	- - -	- - -	- - -	- - -	- - -	.004	.003	.002
	10.3	-.019	-.023	-.016	-.014	-.005	- - -	- - -	- - -	.004	-.001	.007	.004	.009	- - -	- - -	- - -	.009	.016	.010	.009	.007	- - -	- - -	- - -
	12.3	- - -	- - -	- - -	- - -	- - -	-.012	-.003	-.005	- - -	- - -	- - -	- - -	- - -	.006	.006	.007	- - -	- - -	- - -	- - -	- - -	.001	.001	.001
	14.4	-.006	.033	-.005	.000	.003	- - -	- - -	- - -	.005	-.023	-.001	-.011	.004	- - -	- - -	- - -	.003	.020	.004	.002	.000	- - -	- - -	- - -
	16.4	- - -	- - -	- - -	- - -	- - -	-.012	- - -	-.008	- - -	- - -	- - -	- - -	- - -	.005	- - -	.006	- - -	- - -	- - -	- - -	- - -	.000	- - -	- - -

[redacted]

TABLE V.- LATERAL-DIRECTIONAL CHARACTERISTICS NEAR A MACH NUMBER OF 1

Configuration	β	M=0.9; α=14.4			M=1.0; α=0.1			M=1.0; α=7.2			M=1.0; α=14.4		
		C_y	C_n	C_l	C_y	C_n	C_l	C_y	C_n	C_l	C_y	C_n	C_l
Clean; $\delta_p=0^o$, $\delta_p=0^o$, elevons off	5	-0.0937	-0.0010	-0.01361	-0.0777	0.0075	-0.00900	-0.0854	0.0064	-0.01121	-0.1033	0.0030	-0.00977
	4	-.0714	-.0034	-.00815	-.0582	.0030	-.00449	-.0655	.0027	-.00568	-.0804	.0001	-.00465
	3	-.0493	-.0059	-.00247	-.0419	.0007	-.00169	-.0455	-.0005	-.00086	-.0564	-.0047	.00174
	2	-.0287	-.0073	.00274	-.0288	.0008	-.00150	-.0257	-.0046	.00335	-.0328	-.0081	.00815
	1	-.0092	-.0075	.00816	-.0271	.0093	-.00535	-.0064	-.0077	.00843	-.0110	-.0100	.01360
	0	.0082	-.0059	.01186	-.0072	.0037	.00015	.0040	-.0038	.00761	.0088	-.0104	.01810
	-1	.0027	.0140	-.00465	.0096	.0000	.00422	.0038	.0069	.00133	.0268	-.0093	.02126
	-2	.0178	.0167	-.00170	.0131	.0074	.00021	.0076	.0151	-.00217	.0168	.0180	-.00785
	-3	.0382	.0159	.00392	.0293	.0059	-.00023	.0268	.0110	.00150	.0436	.0090	-.00202
	-4	.0589	.0141	.00903	.0475	.0028	.00260	.0477	.0069	.00709	.0662	.0049	.00357
	-5	.0803	.0127	.01448	.0678	-.0039	.00870	.0679	.0033	.01175	.0913	-.0047	.01020
Clean; one elevon; $\delta_e=10^o$	-5	-.0359	-.0427	.01463	-.0568	-.0127	.00873	-.0500	-.0240	.01607	-.0554	-.0359	.01820
	-4	-.0147	-.0450	.02024	-.0357	-.0194	.01484	-.0282	-.0290	.02101	-.0310	-.0399	.02471
	-3	.0058	-.0460	.02519	-.0154	-.0254	.02051	-.0088	-.0316	.02490	-.0074	-.0437	.03079
	-2	.0220	-.0437	.02727	.0038	-.0298	.02602	.0128	-.0399	.02788	.0055	-.0374	.02758
	-1	.0355	-.0392	.02580	.0024	-.0180	.01844	.0267	-.0351	.02955	.0245	-.0369	.02789
	0	.0377	-.0271	.01732	.0223	-.0253	.02355	.0334	-.0283	.02254	.0184	-.0149	.01246
	1	.0588	-.0282	.02263	.0448	-.0485	.02476	.0447	-.0269	.02167	.0431	-.0196	.01863
	2	.0804	-.0293	.02832	.0587	-.0500	.02608	.0586	-.0275	.02271	.0692	-.0260	.02533
	3	.1009	-.0300	.03385	.0644	-.0322	.02729	.0774	-.0288	.02925	.1012	-.0424	.03262
	4	.1228	-.0337	.03998	.0966	-.0822	.02340	.0973	-.0323	.03393	.1288	-.0494	.03882
	5	.1445	-.0363	.04607	.1050	-.0517	.03360	.1158	-.0354	.03841	.1557	-.0578	.04589
Clean; one elevon; $\delta_e=-10^o$	-5	-.1159	.0138	-.03006	-.0816	.0137	-.00463	-.0998	.0169	-.01991	-.1321	.0234	-.03267
	-4	-.0952	.0113	-.02391	-.0629	.0092	.00050	-.0791	.0131	-.01350	-.1062	.0183	-.02574
	-3	-.0695	.0090	-.01785	-.0433	.0045	.00521	-.0601	.0102	-.00805	-.0811	.0135	-.01911
	-2	-.0497	.0068	-.01255	-.0247	.0003	.00085	-.0397	.0070	-.00257	-.0574	.0101	-.01266
	-1	-.0287	.0054	-.00655	-.0196	.0073	.00551	-.0207	.0043	.00163	-.0326	.0050	-.00550
	0	-.0089	.0049	-.00130	-.0021	-.0087	.00580	-.0095	.0073	.00072	-.0102	.0028	.00031
	1	.0089	.0056	.00349	.0076	-.0070	.00609	-.0041	.0137	-.00222	.0085	.0033	.00162
	2	.0000	.0264	-.01557	.0128	.0101	.00858	.0058	.0165	-.00391	.0021	.0261	-.01456
	3	.0171	.0288	-.01242	.0276	.0109	.01051	.0170	.0206	-.00275	.0226	.0203	-.02026
	4	.0389	.0272	-.00671	.0466	.0078	.01373	.0388	.0150	.00347	.0468	.0137	-.01410
	5	.0620	.0234	-.00120	.0661	.0020	.01865	.0597	.0118	.00970	.0730	.0042	-.00645
Clean; one elevon; $\delta_e=-30^o$	5	-.0968	.0073	-.00849	-.0756	.0207	.00907	-.0829	.0145	.00397	-.1110	.0152	-.00773
	4	-.0752	.0054	-.00222	-.0587	.0182	.01334	-.0629	.0107	.00954	-.0874	.0111	-.00176
	3	-.0543	.0035	.00314	-.0425	.0158	.01621	-.0448	.0086	.01482	-.0637	.0069	.00436
	2	-.0303	.0019	.00793	-.0329	.0180	.01556	-.0248	.0052	.02075	-.0409	.0048	.01029
	1	-.0116	.0019	.01241	-.0173	.0152	.01966	-.0063	.0030	.02575	-.0189	.0018	.01487
	0	.0060	.0032	.01477	-.0007	.0119	.02387	.0070	.0056	.02612	.0008	-.0010	.01622
	-1	-.0065	.0276	-.00252	.0140	.0094	.02722	.0122	.0111	.02031	.0166	.0003	.01564
	-2	.0127	.0274	.00271	.0257	.0096	.02808	.0221	.0126	.01916	.0179	.0184	.00731
	-3	.0352	.0217	.00750	.0475	-.0145	.02659	.0325	.0174	.01952	.0385	.0138	.00335
	-4	.0569	.0189	.01375	.0534	.0026	.02962	.0477	.0184	.02310	.0641	.0018	.01169
	-5	.0793	.0156	.01920	.0798	-.0224	.03044	.0668	.0151	.02780	.0897	-.0017	.01663
Clean; one yaw flap $\delta_y=20^o$	5	-.0840	-.0089	-.01066	-.0550	-.0135	-.00726	-.0659	-.0105	-.00790	-.0918	-.0055	-.01334
	4	-.0614	-.0118	-.00496	-.0346	-.0197	-.00224	-.0464	-.0143	-.00248	-.0723	-.0096	-.00883
	3	-.0405	-.0145	.00035	-.0158	-.0254	.00207	-.0266	-.0181	.00277	-.0509	-.0131	-.00638
	2	-.0183	-.0169	.00603	-.0009	-.0270	.00245	-.0067	-.0216	.00823	-.0235	-.0150	.00401
	1	.0025	-.0190	.01140	.0123	-.0268	.00253	.0138	-.0258	.01340	-.0042	-.0174	.00636
	0	.0210	-.0193	.01633	.0187	-.0210	.00136	.0293	-.0266	.01362	.0147	-.0195	.00876
	-1	.0284	-.0083	.00077	.0348	-.0279	.00352	.0311	-.0173	.00742	.0254	-.0144	.00629
	-2	.0382	-.0013	-.00109	.0447	-.0216	.00475	.0370	-.0117	.00485	.0452	-.0232	.00766
	-3	.0585	-.0035	.00470	.0615	-.0258	.00729	.0506	-.0107	.00612	.0639	-.0172	.01174
	-4	.0778	-.0048	.01016	.0800	-.0303	.01125	.0695	-.0142	.01045	.0845	-.0207	.01587
	-5	.1005	-.0073	.01554	.1104	-.0665	.01199	.0871	-.0164	.01444	.1032	-.0203	.01943
Clean; one yaw flap $\delta_y=30^o$	5	-.0710	-.0216	-.00971	-.0536	-.0105	-.01149	-.0560	-.0201	-.00835	-.0831	-.0138	-.01085
	4	-.0483	-.0251	-.00413	-.0393	-.0122	-.01060	-.0357	-.0248	-.00277	-.0579	-.0191	-.00421
	3	-.0257	-.0279	.00119	-.0344	-.0061	-.01299	-.0160	-.0289	.00275	-.0363	-.0228	.00101
	2	-.0045	-.0306	.00709	-.0193	-.0097	-.00956	.0056	-.0337	.00845	-.0131	-.0290	.00430
	1	.0162	-.0318	.01256	.0023	-.0170	-.00428	.0268	-.0392	.01332	.0063	-.0324	.00651
	0	.0361	-.0325	.01739	.0235	-.0254	.00162	.0440	-.0403	.01563	.0232	-.0289	.00849
	-1	.0397	-.0189	.00433	.0446	-.0329	.00779	.0477	-.0324	.01098	.0306	-.0170	.00532
	-2	.0519	-.0138	.00334	.0653	-.0411	.01284	.0523	-.0256	.00666	.0489	-.0175	.00732
	-3	.0719	-.0147	.00854	.0863	-.0533	.01611	.0673	-.0261	.00978	.0702	-.0203	.01130
	-4	.0915	-.0159	.01360	.0993	-.0500	.01919	.0872	-.0303	.01412	.0915	-.0244	.01549
	-5	.1157	-.0209	.01922	.1154	-.0504	.02240	.1050	-.0331	.01838	.1154	-.0382	.01990

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TABLE VI.- LATERAL-DIRECTIONAL DERIVATIVES FOR A MODIFIED 13° HALF-CONE
(cf. ref. 8)

	α, deg	M=0.6	M=0.9	M=1.0	M=1.1	M=1.3
C_{y_β} per deg	0.1	-0.0096	-0.0142	-0.0152	-0.0144	-0.0142
	7.2	-.0116	-.0173	-.0161	-.0158	-.0163
	14.4	-.0168	-.0212	-.0194	-.0192	-.0200
C_{n_β} per deg	.1	-.0010	.0004	.0017	.0016	.0016
	7.2	-.0011	.0008	.0010	.0007	.0008
	14.4	-.0018	.0000	.0000	.0000	.0004
C_{l_β} per deg	.1	-.0016	-.0016	-.0018	-.0017	-.0015
	7.2	-.0030	-.0028	-.0028	-.0026	-.0027
	14.4	-.0041	-.0032	-.0036	-.0032	-.0036

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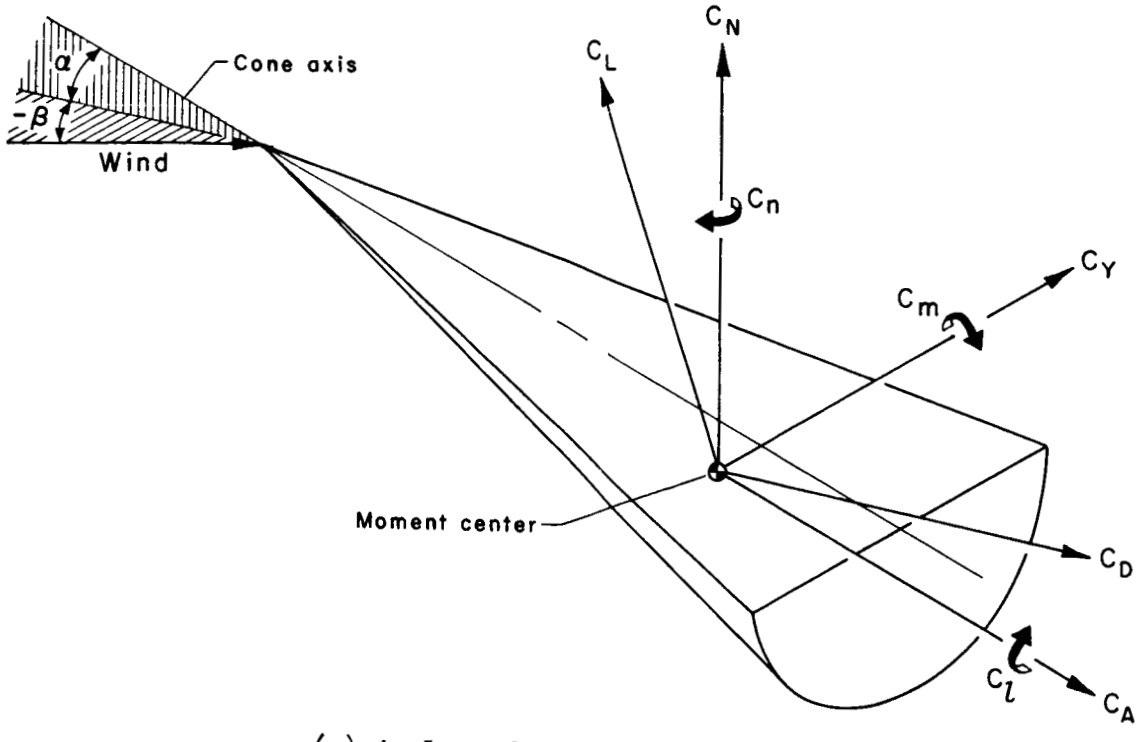
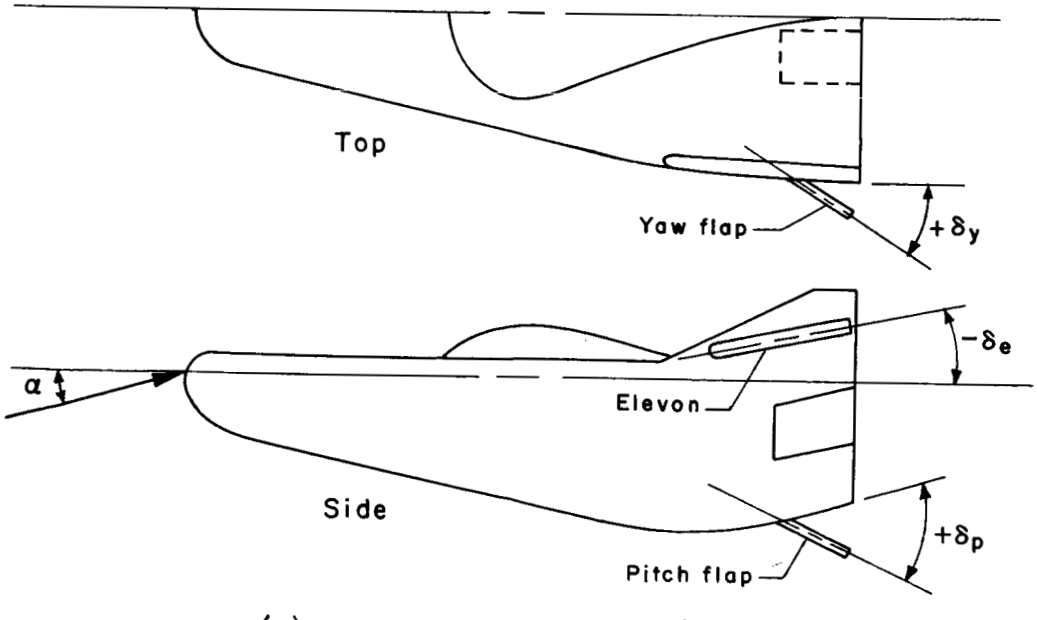


(a) Angles, forces, and moments.



(b) Control deflection angles.

Figure 1.- Nomenclature.

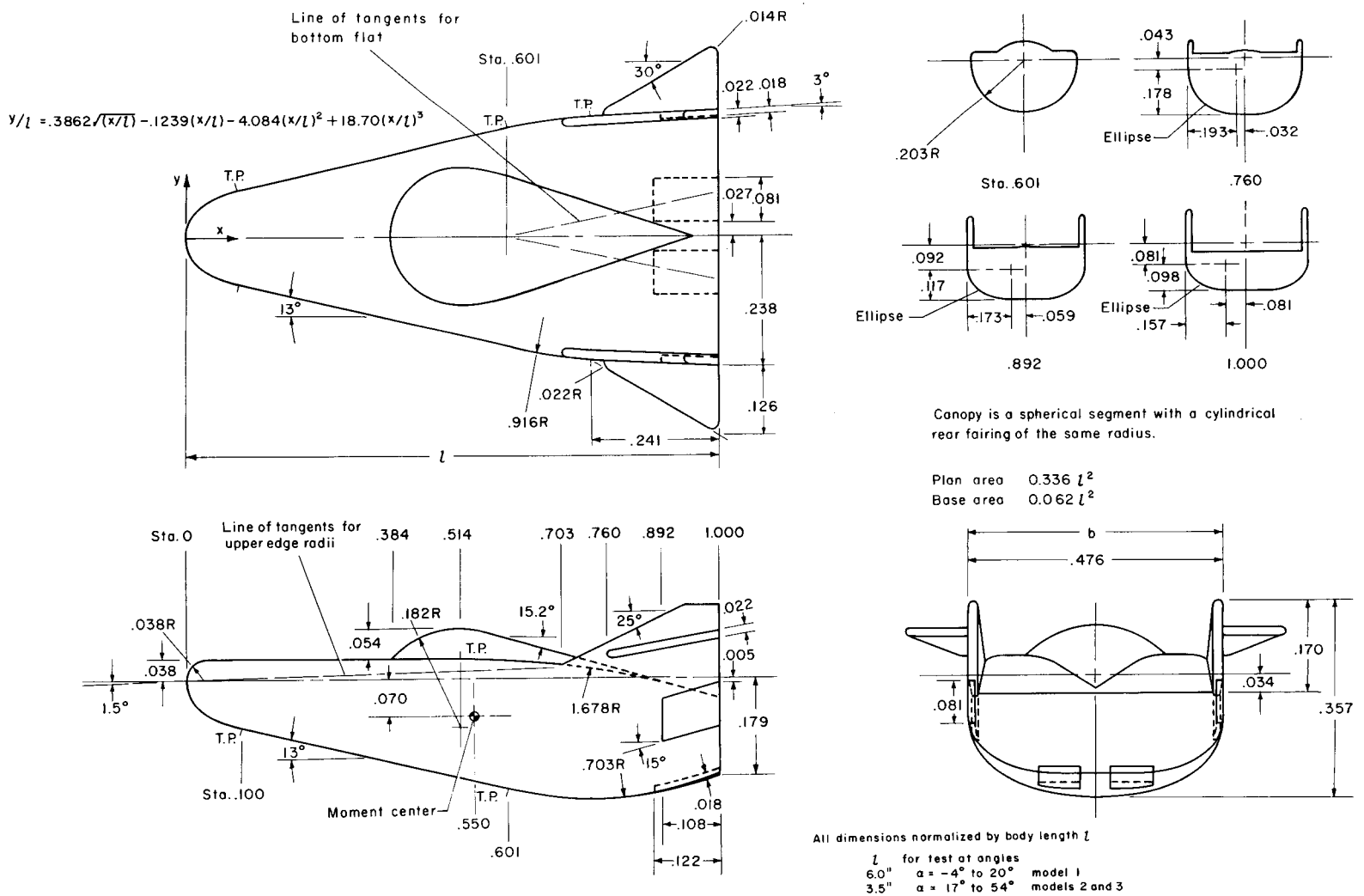


Figure 2.- Basic geometry of models 1, 2, and 3.

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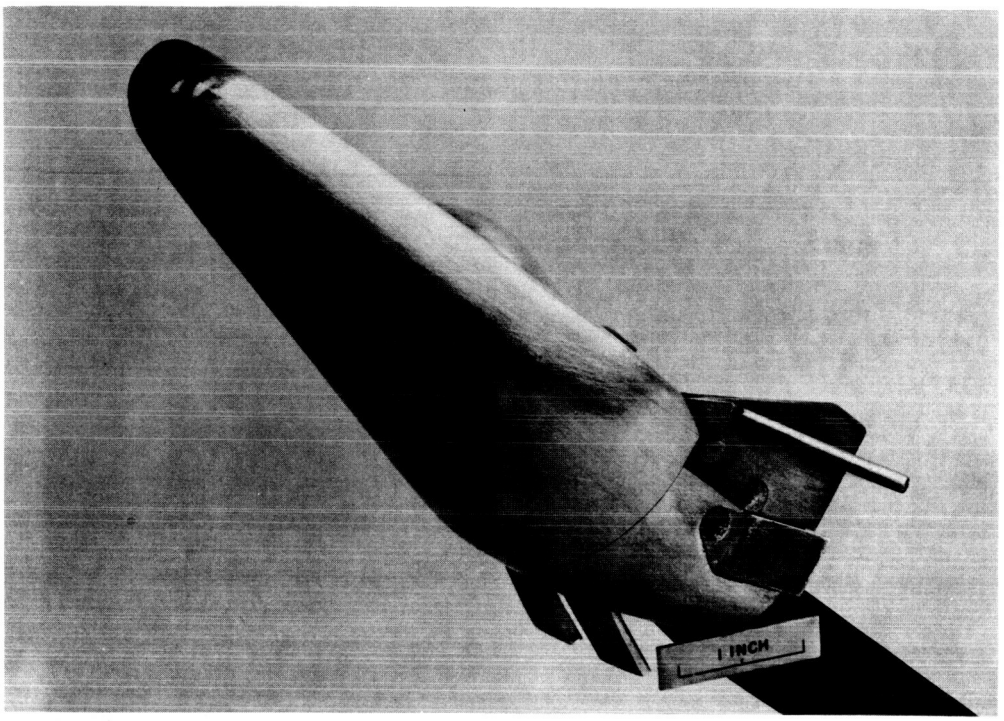
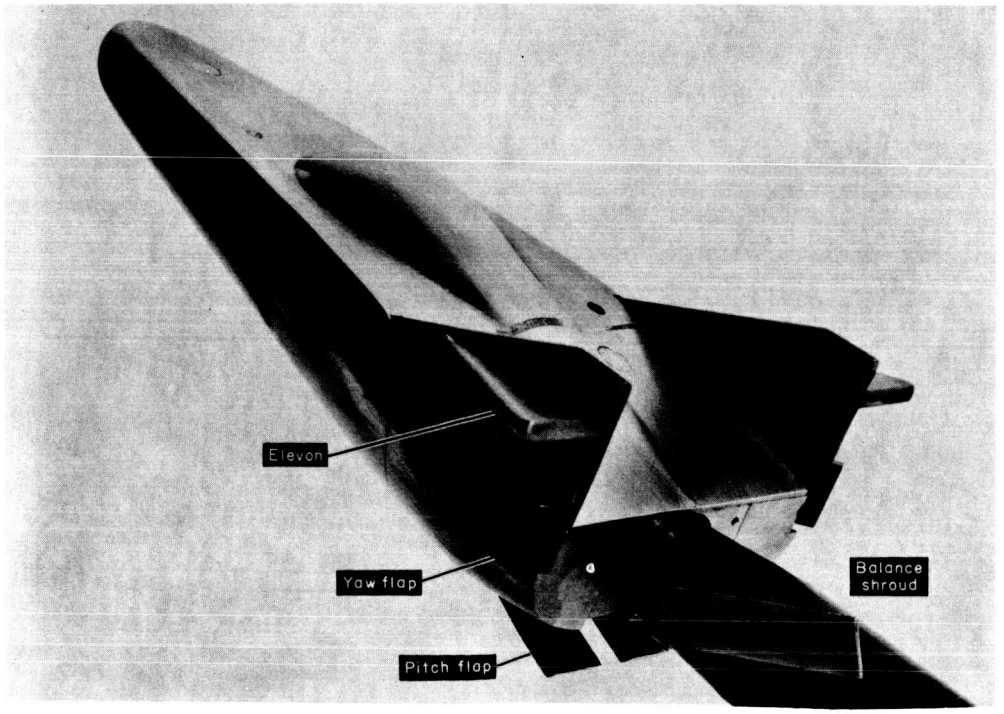


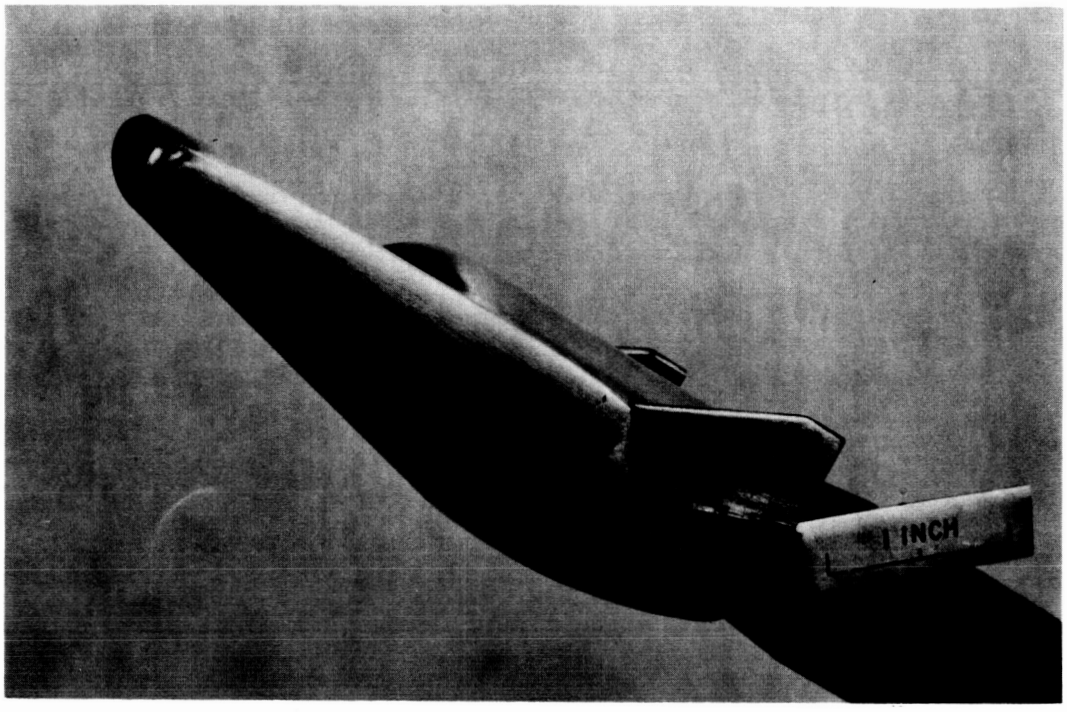
A-26821.1



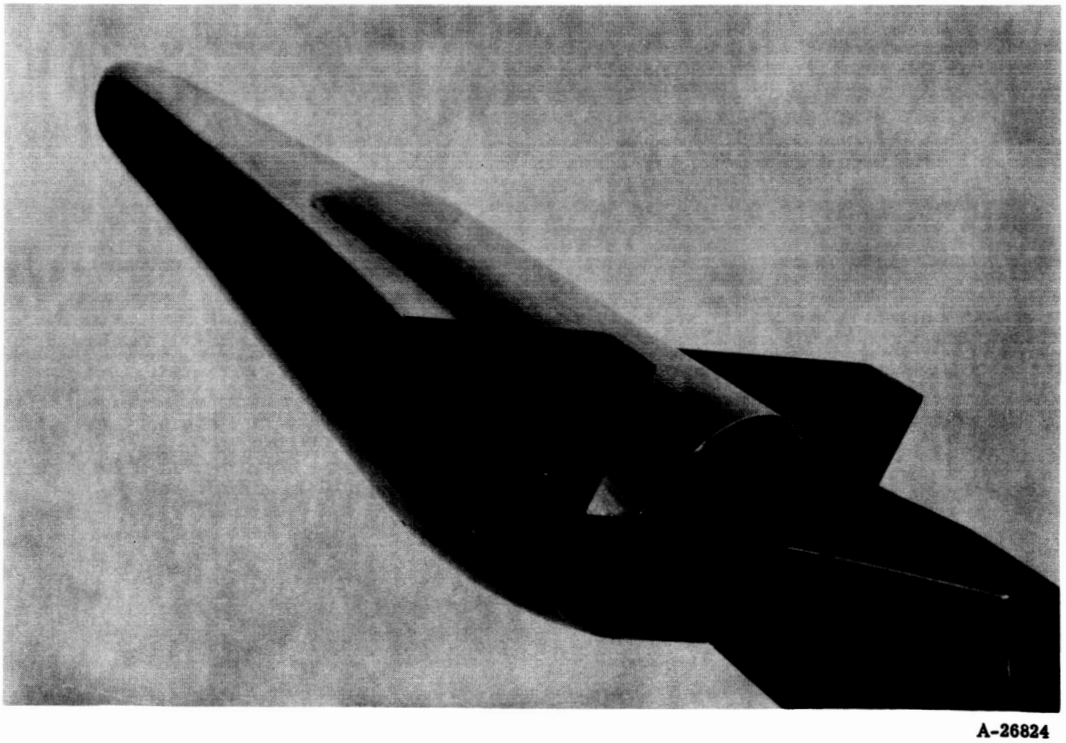
A-26822.1

(a) Model 1, tested at angles of attack from -4° to $+20^{\circ}$, l = 6 in.

Figure 3.- Model photographs.



A-26823



A-26824

(b) Model 2, tested at angles of attack from 17° to 32°, l = 3.5 in.

Figure 3.- Continued.

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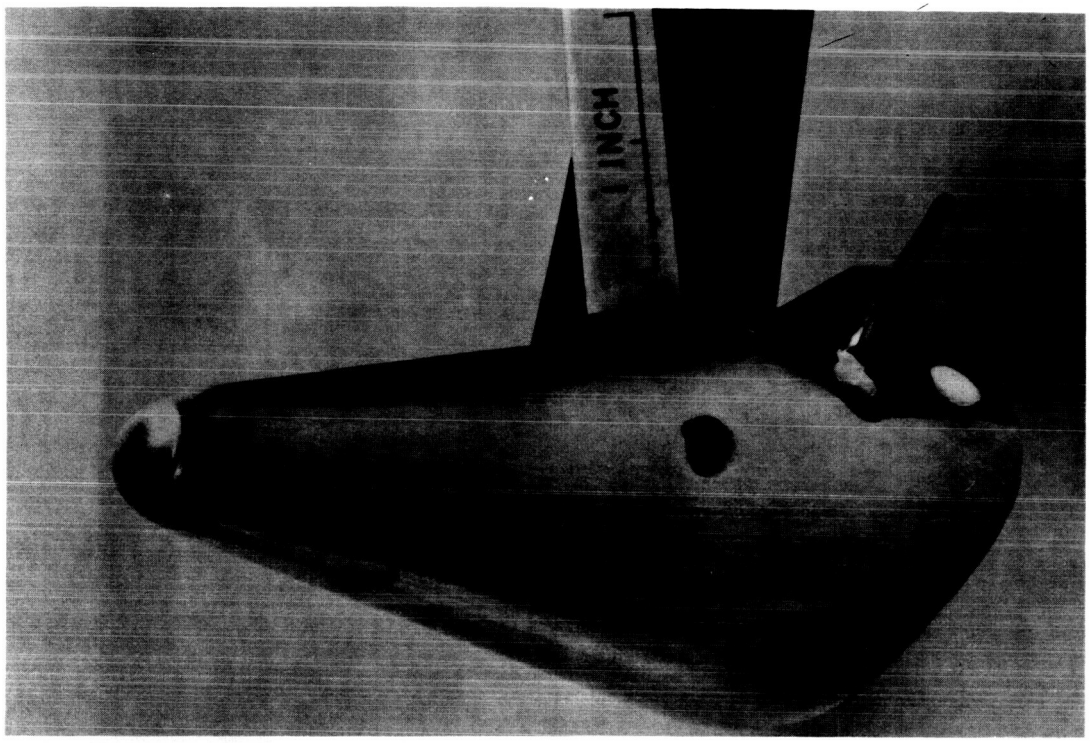
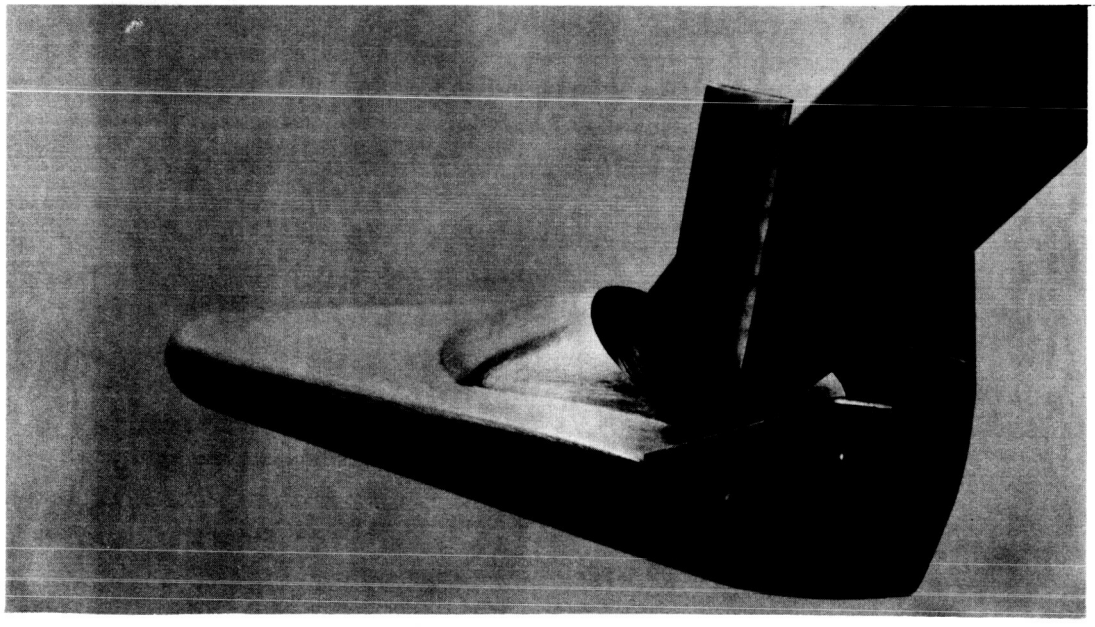


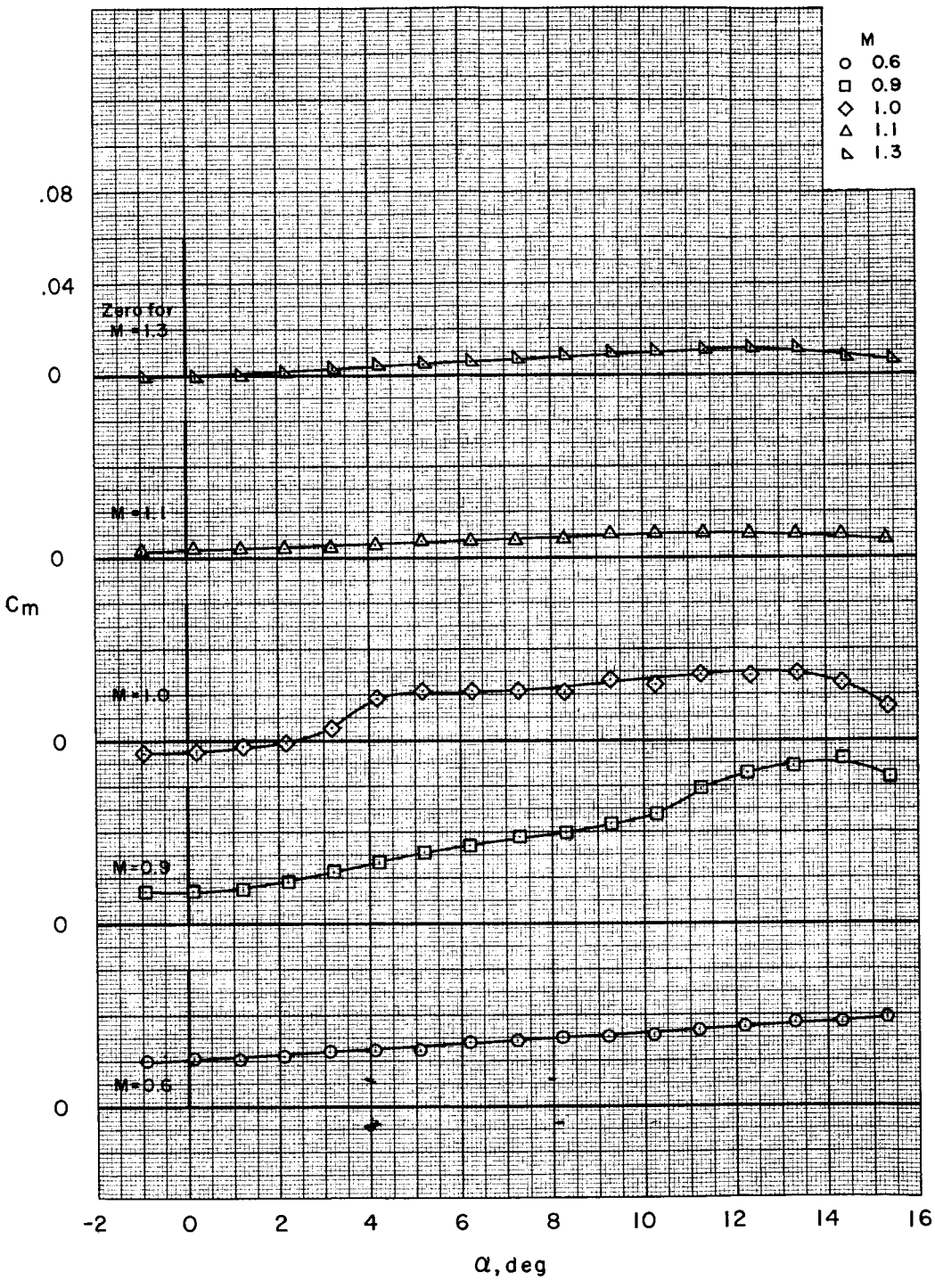
A-26825.1



A-26826

(c) Model 3, tested at angles of attack from 32° to 54°, l = 3.5 in.

Figure 3.- Concluded.



(a) Transonic speeds.

Figure 4.- Pitching-moment coefficient of the clean configuration (δ_p=0, δ_y=0, elevons off).

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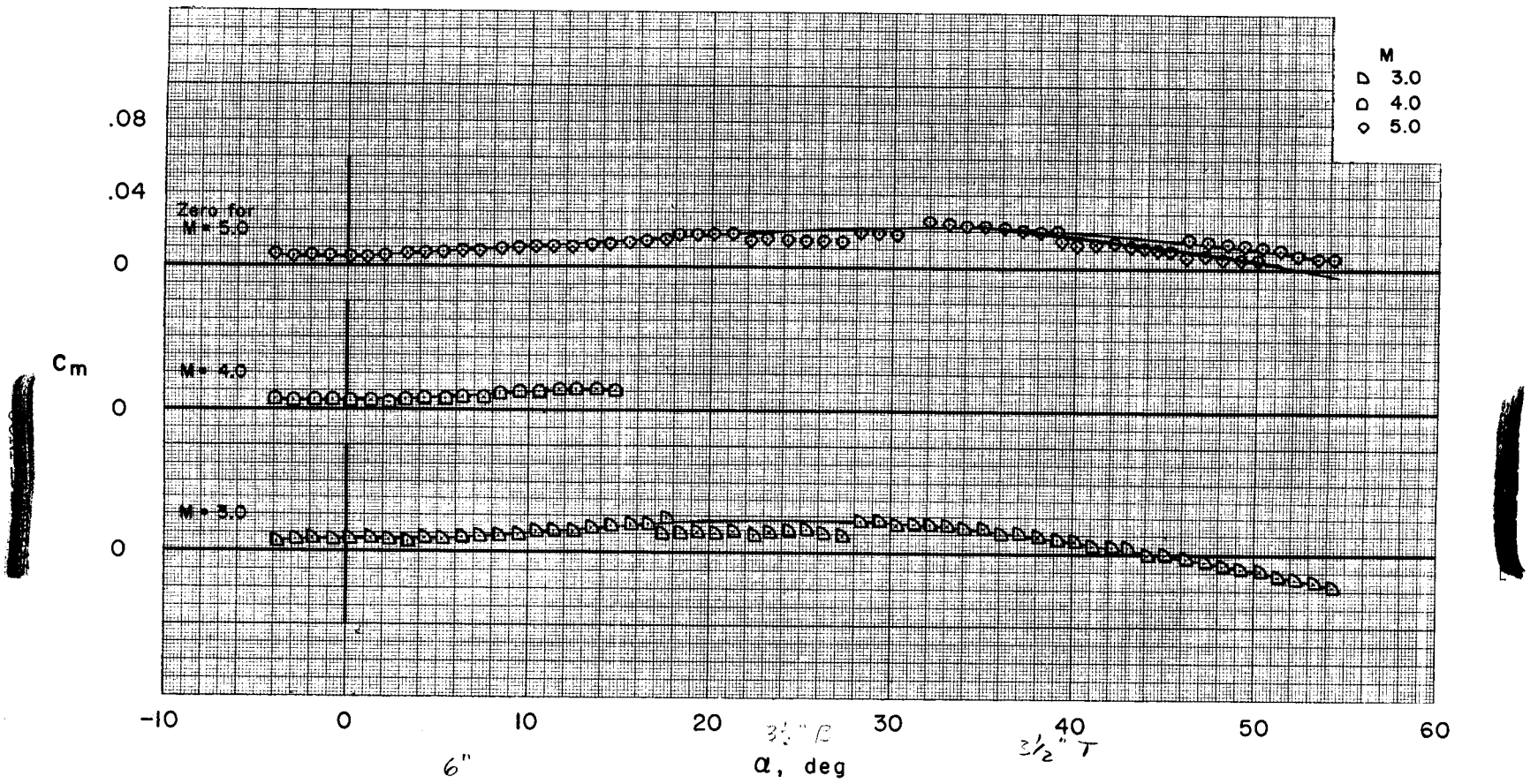
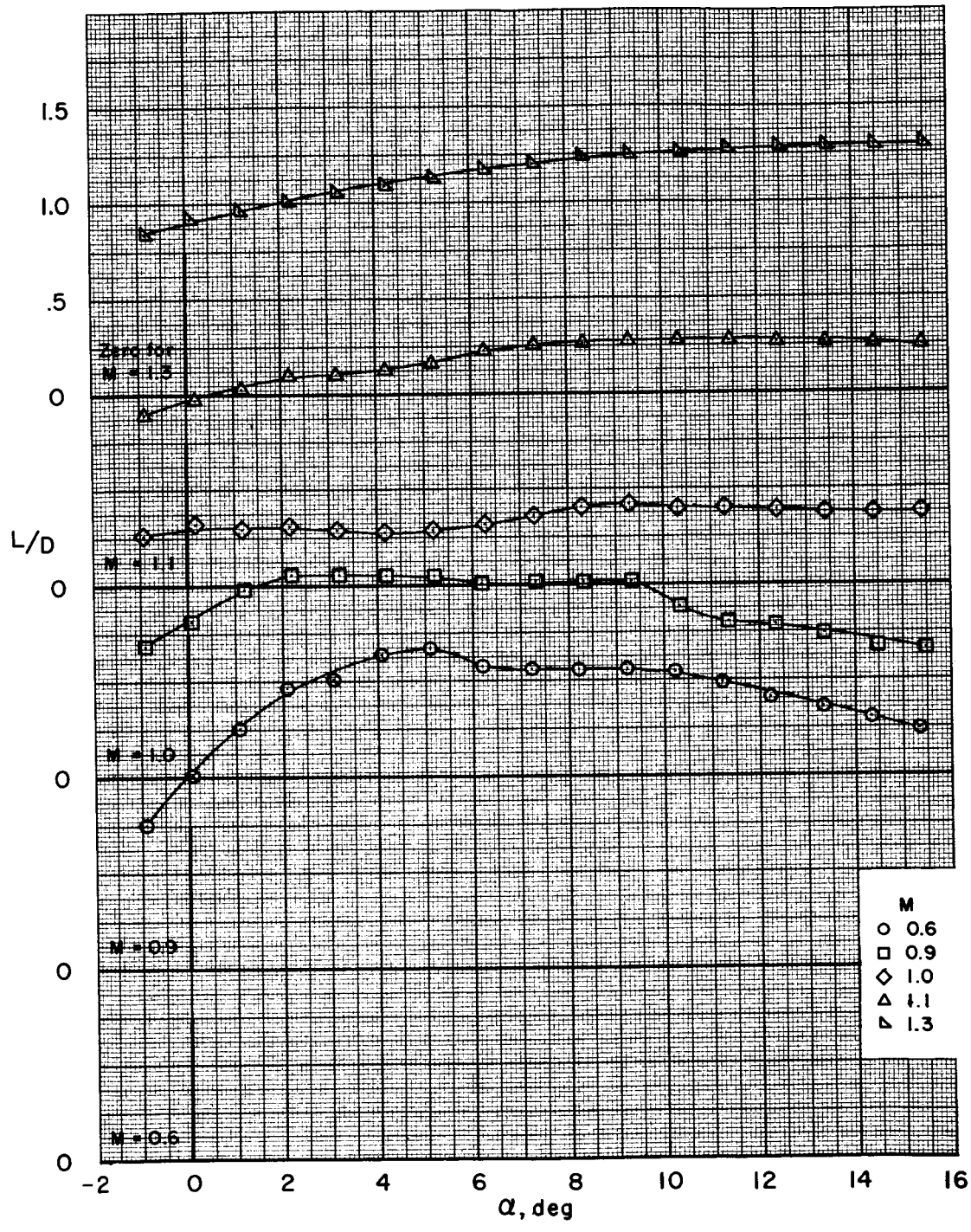


(b) Supersonic speeds.

Figure 4.- Concluded.



(a) Transonic speeds.

Figure 5.- Lift-drag ratio of the clean configuration (δ_p=0, δ_y=0, elevons off).

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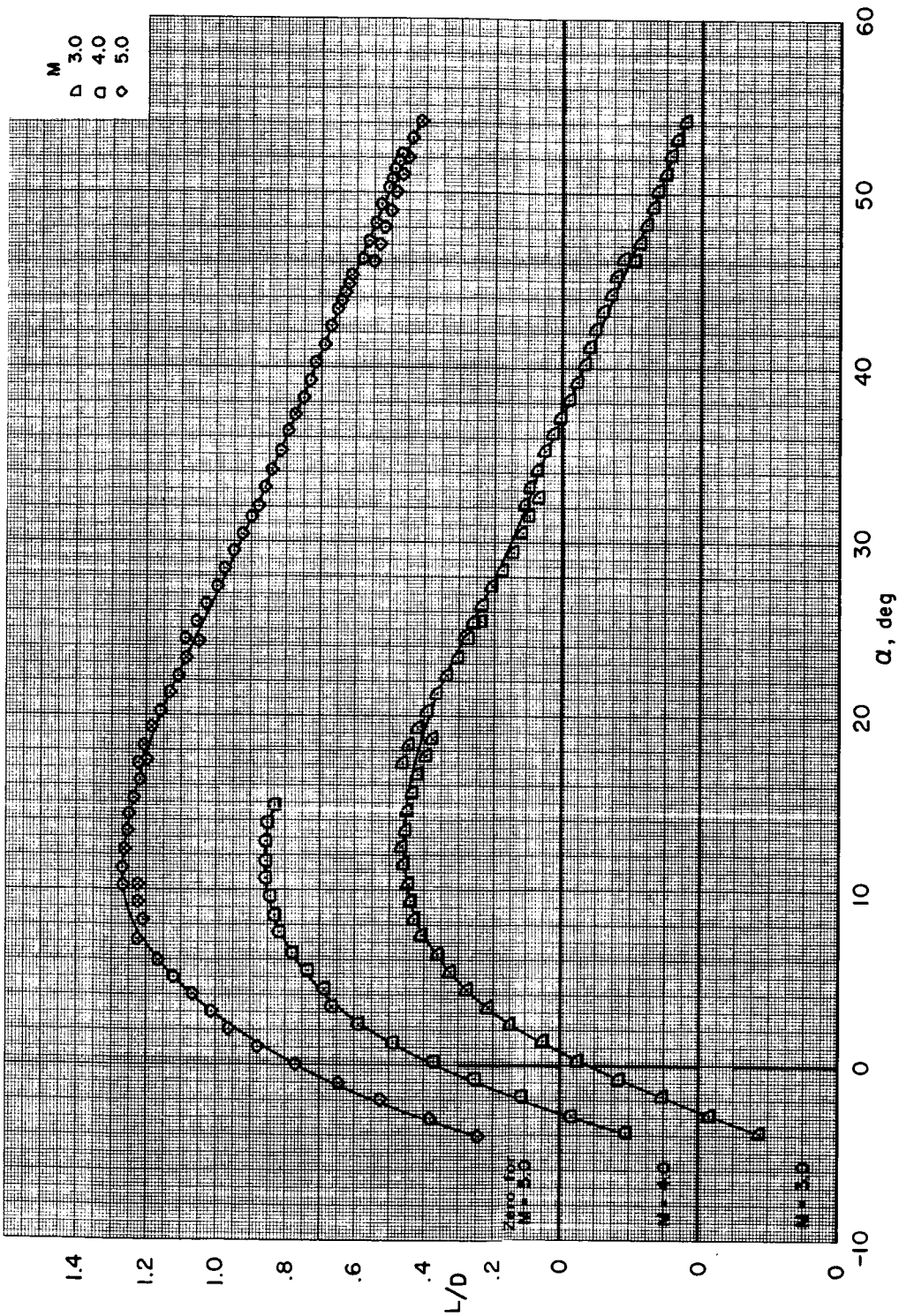

(b) Supersonic speeds.

Figure 5.- Concluded.

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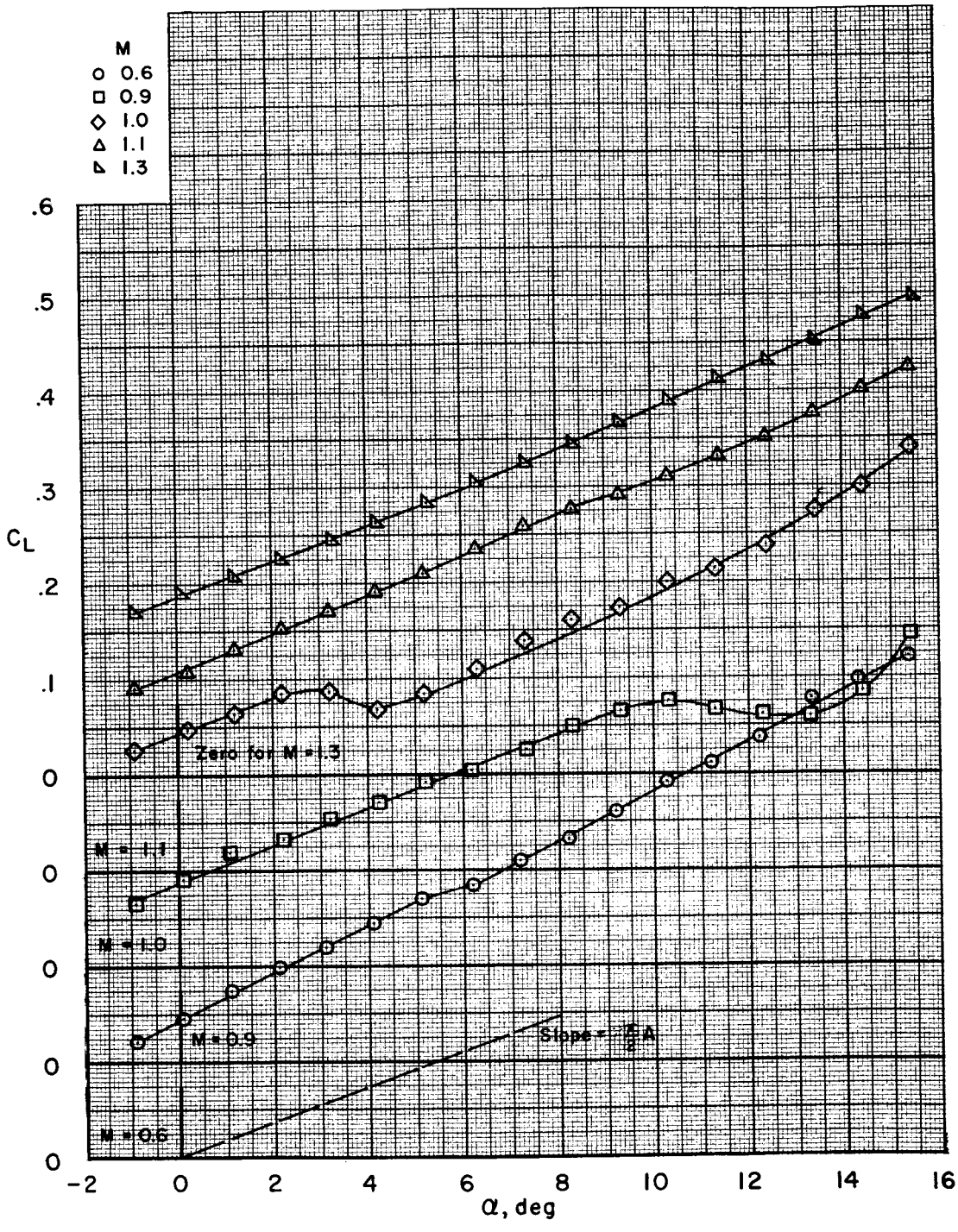
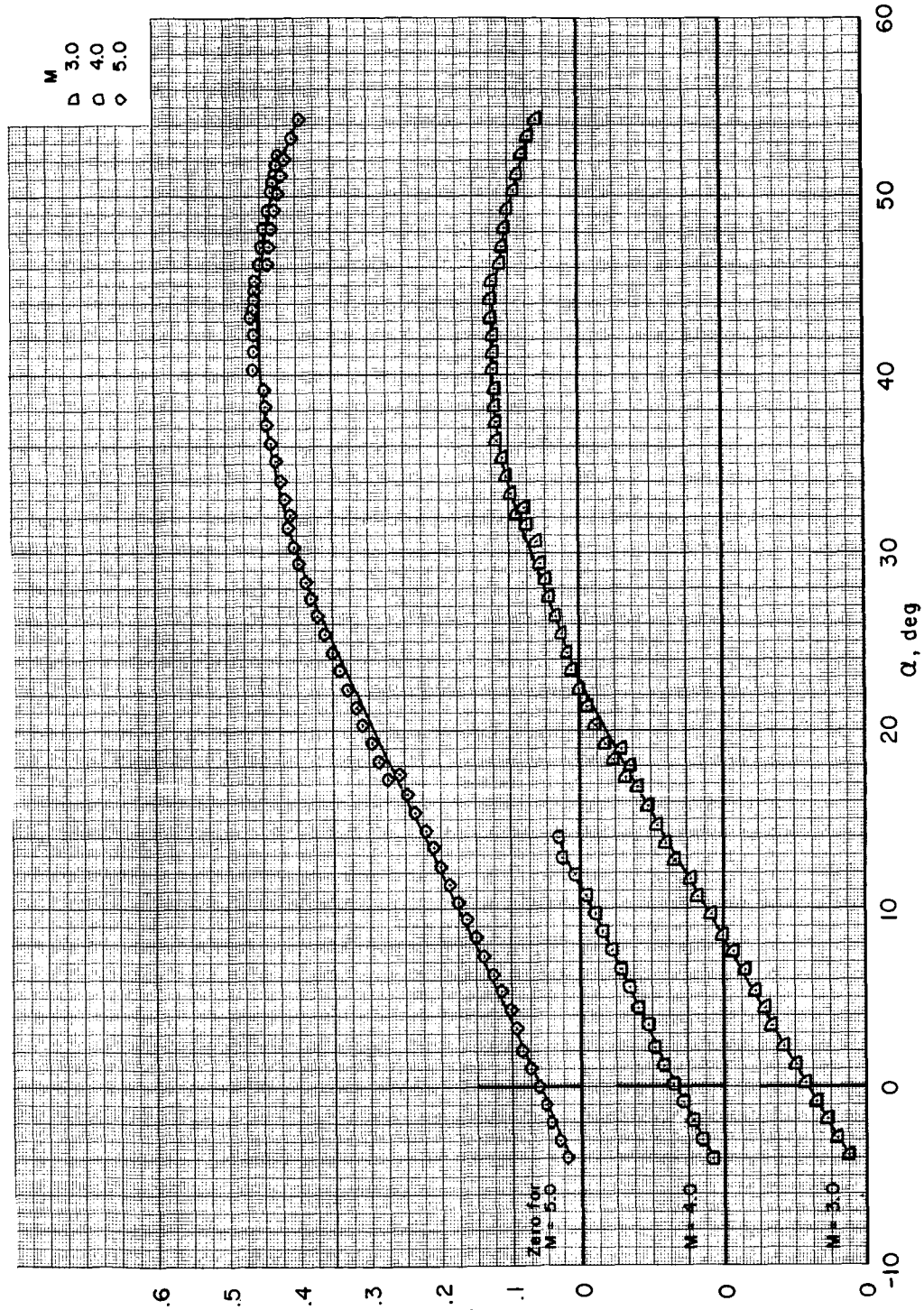


(a) Transonic speeds.

Figure 6.- Lift coefficient of the clean configuration (δ_p=0, δ_y=0, elevons off).

A 4 8 6



(b) Supersonic speeds.

Figure 6.- Concluded.

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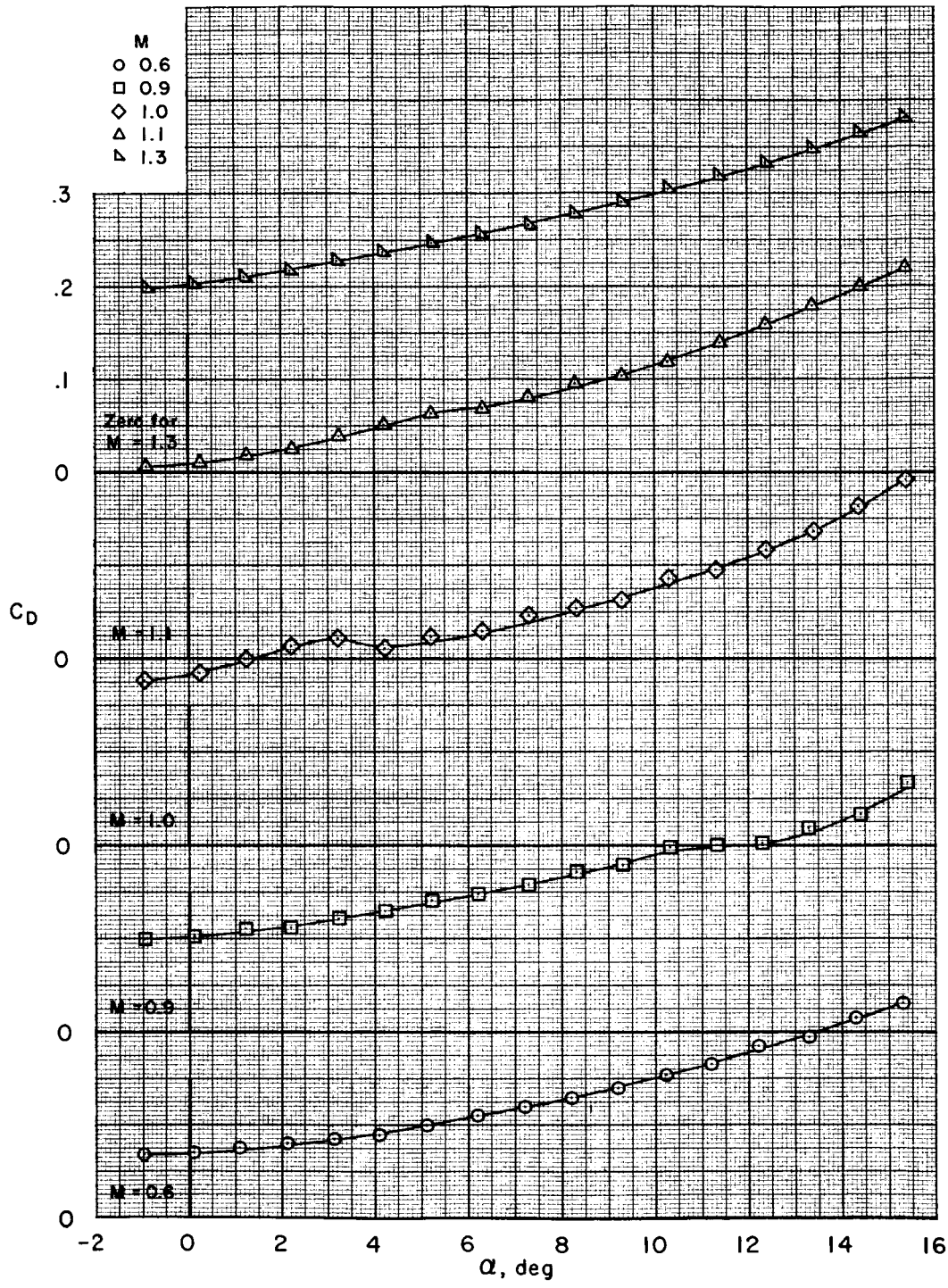
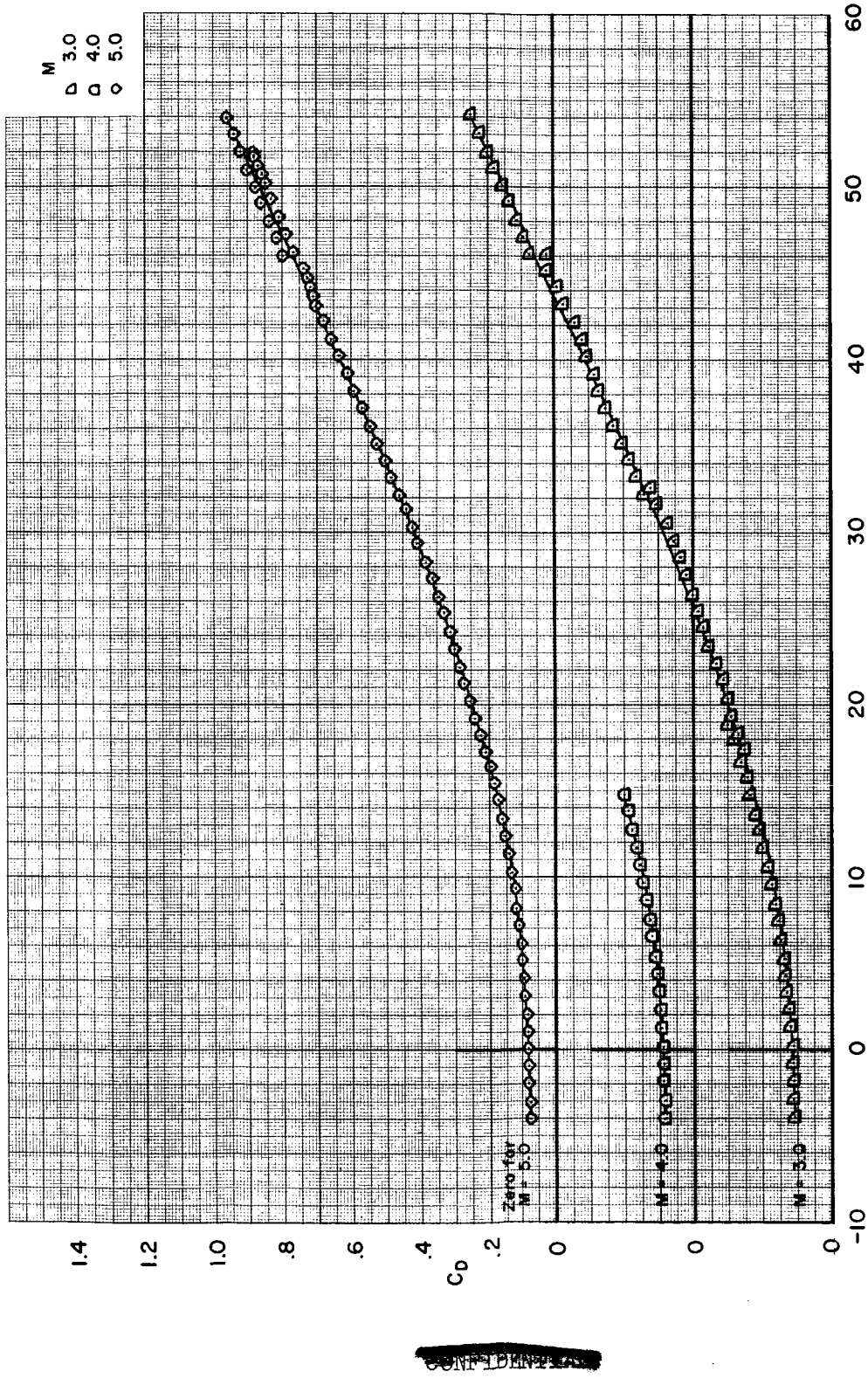


(a) Transonic speeds.

Figure 7.- Drag coefficient of clean configuration (δ_p=0, δ_y=0, elevons off).

A 4 8 6



(b) Supersonic speeds.

Figure 7.- Concluded.

A-4866

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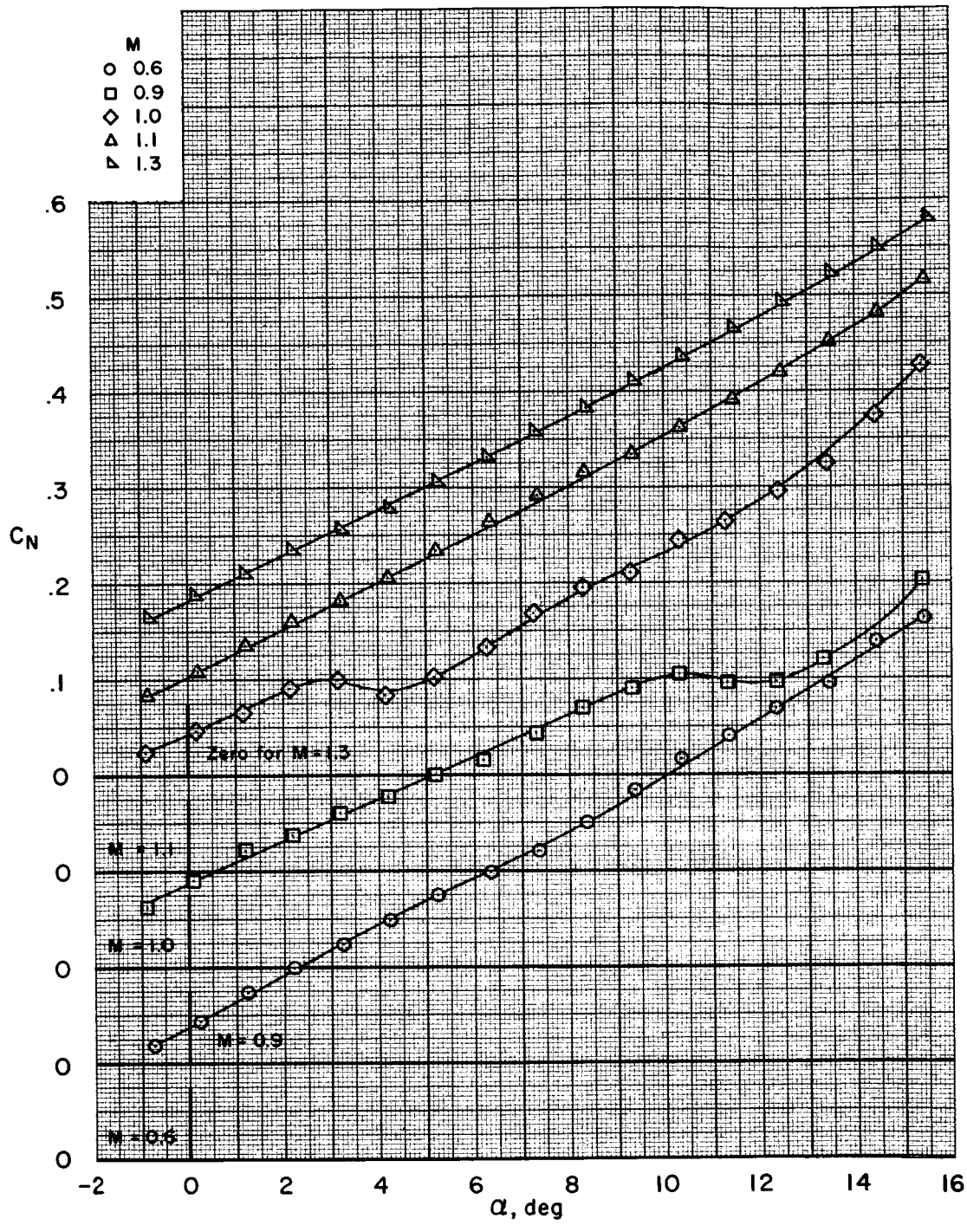

(a) Transonic speeds.

Figure 8.- Normal-force coefficient of clean configuration (δ_p=0, δ_y=0, elevons off).

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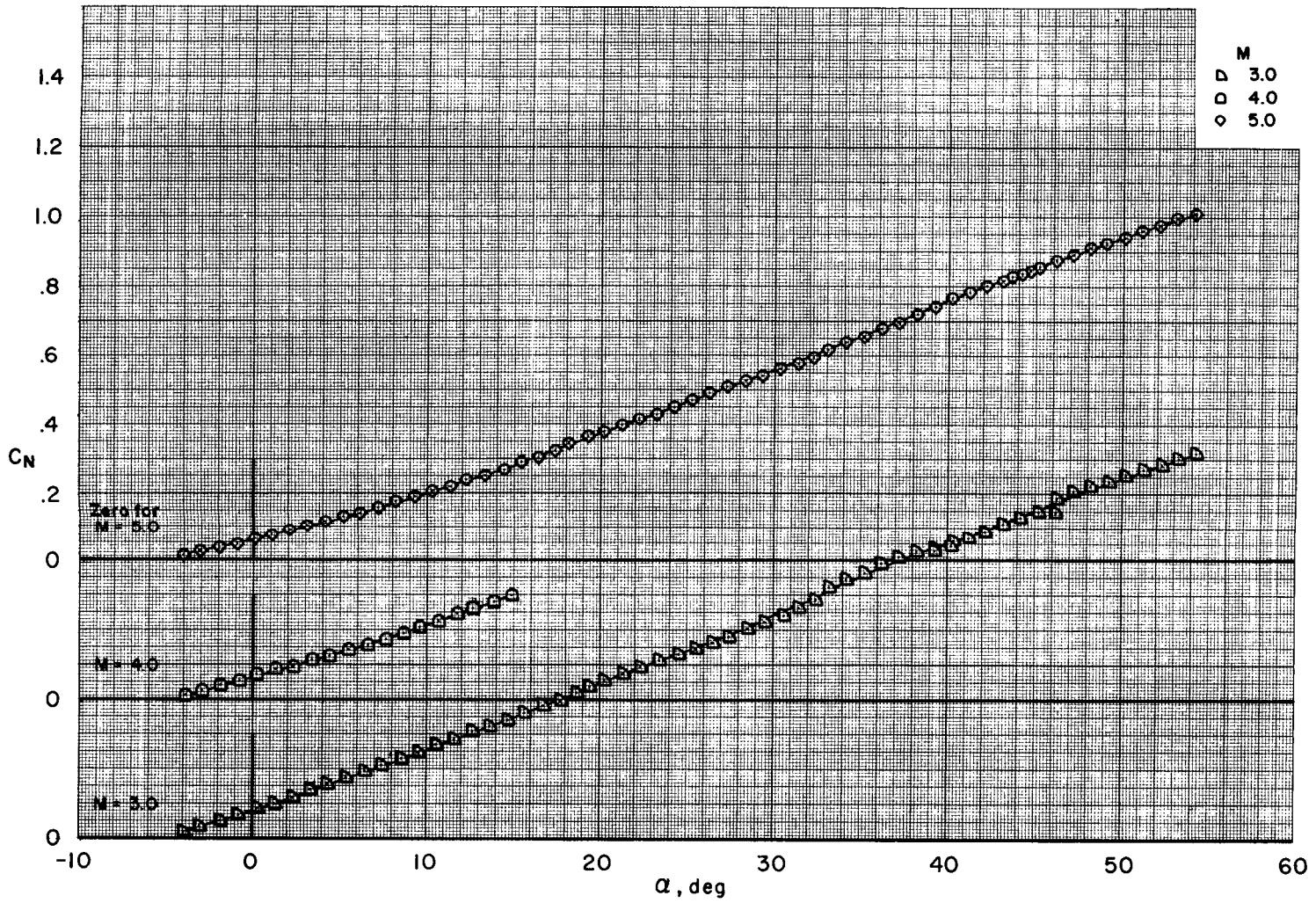

(b) Supersonic speeds.

Figure 8.- Concluded.

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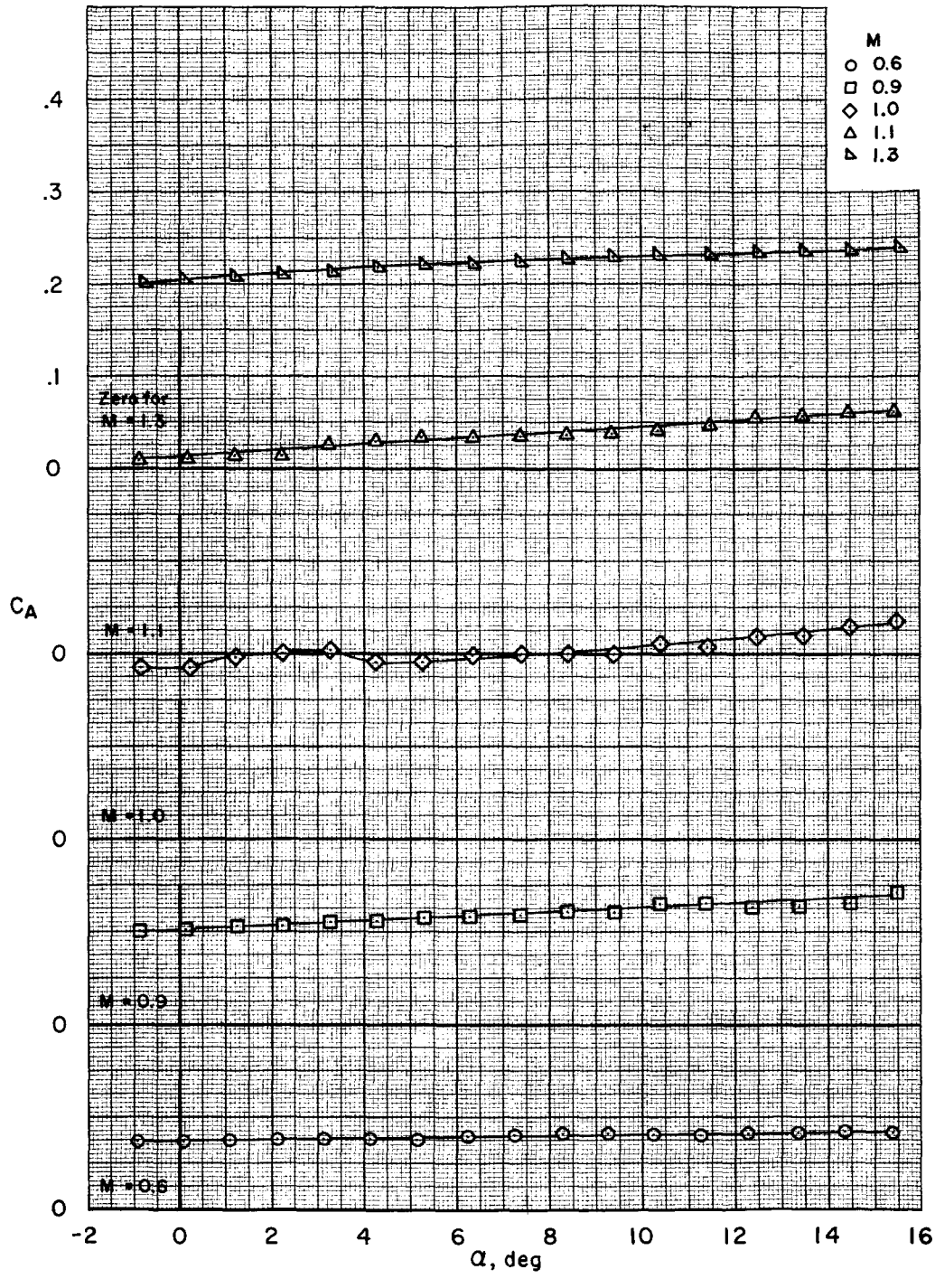
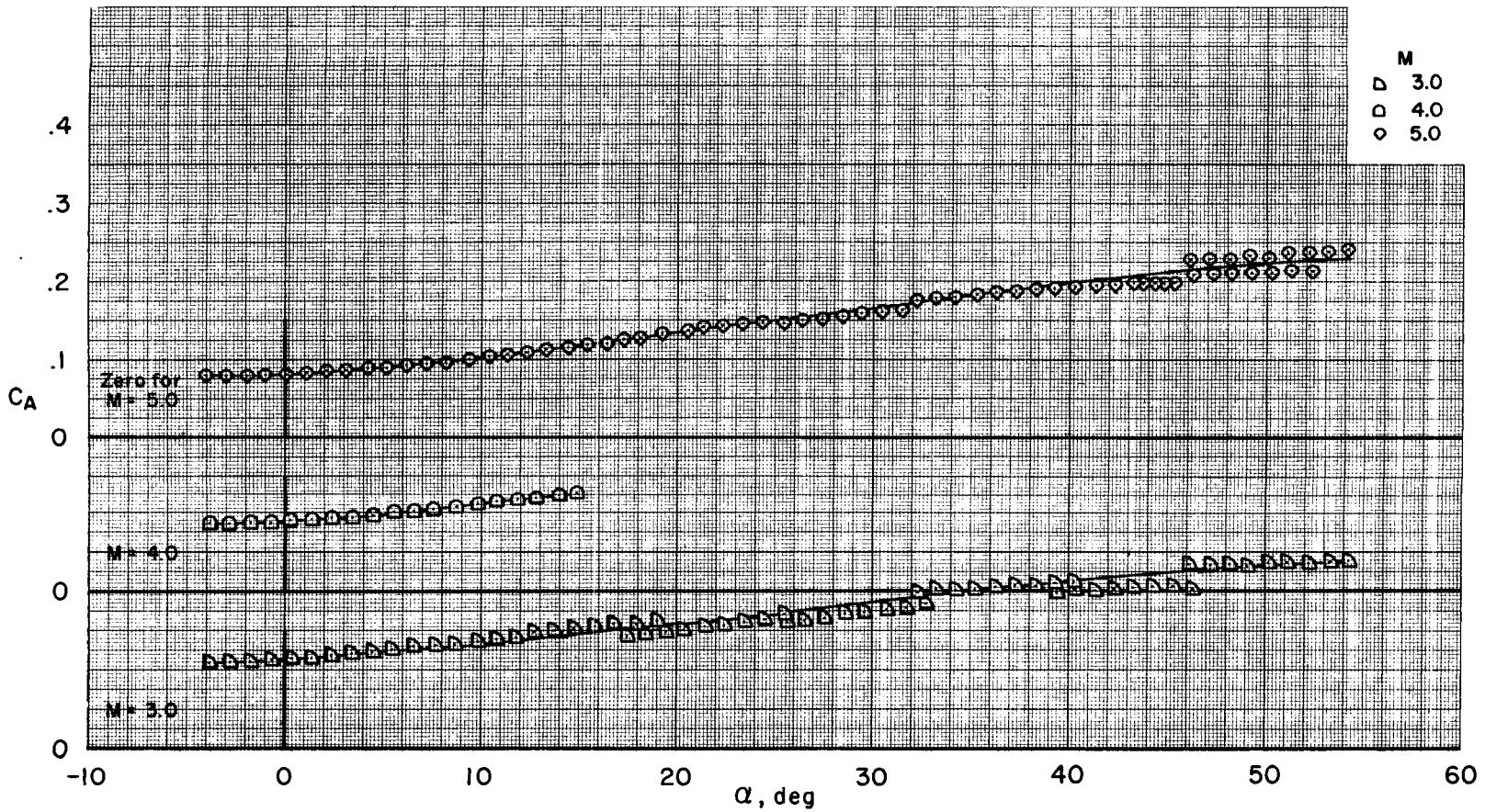


(a) Transonic speeds.

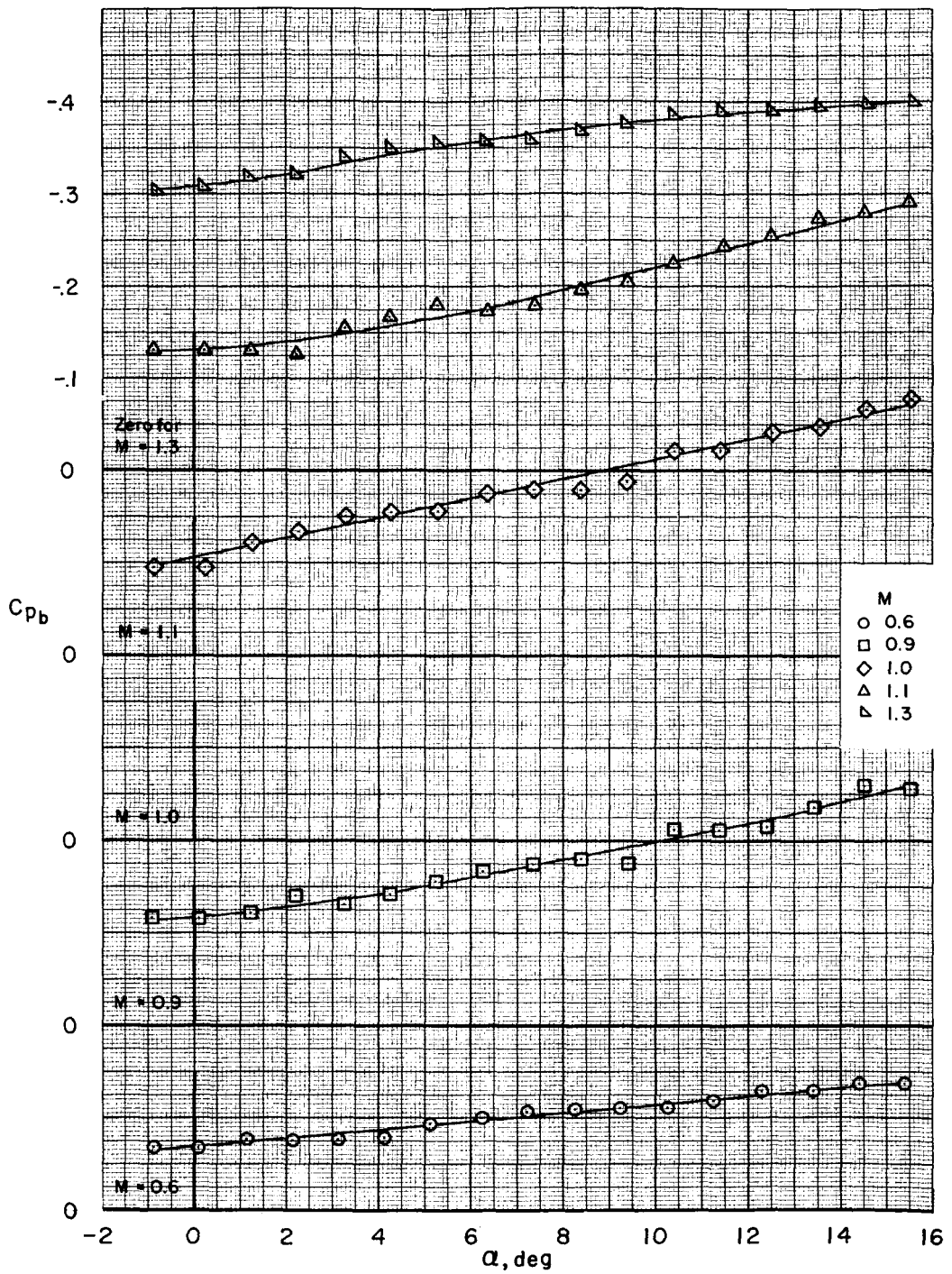
Figure 9.- Axial-force coefficient of clean configuration (δ_p=0, δ_y=0, elevons off).

A486



(b) Supersonic speeds.

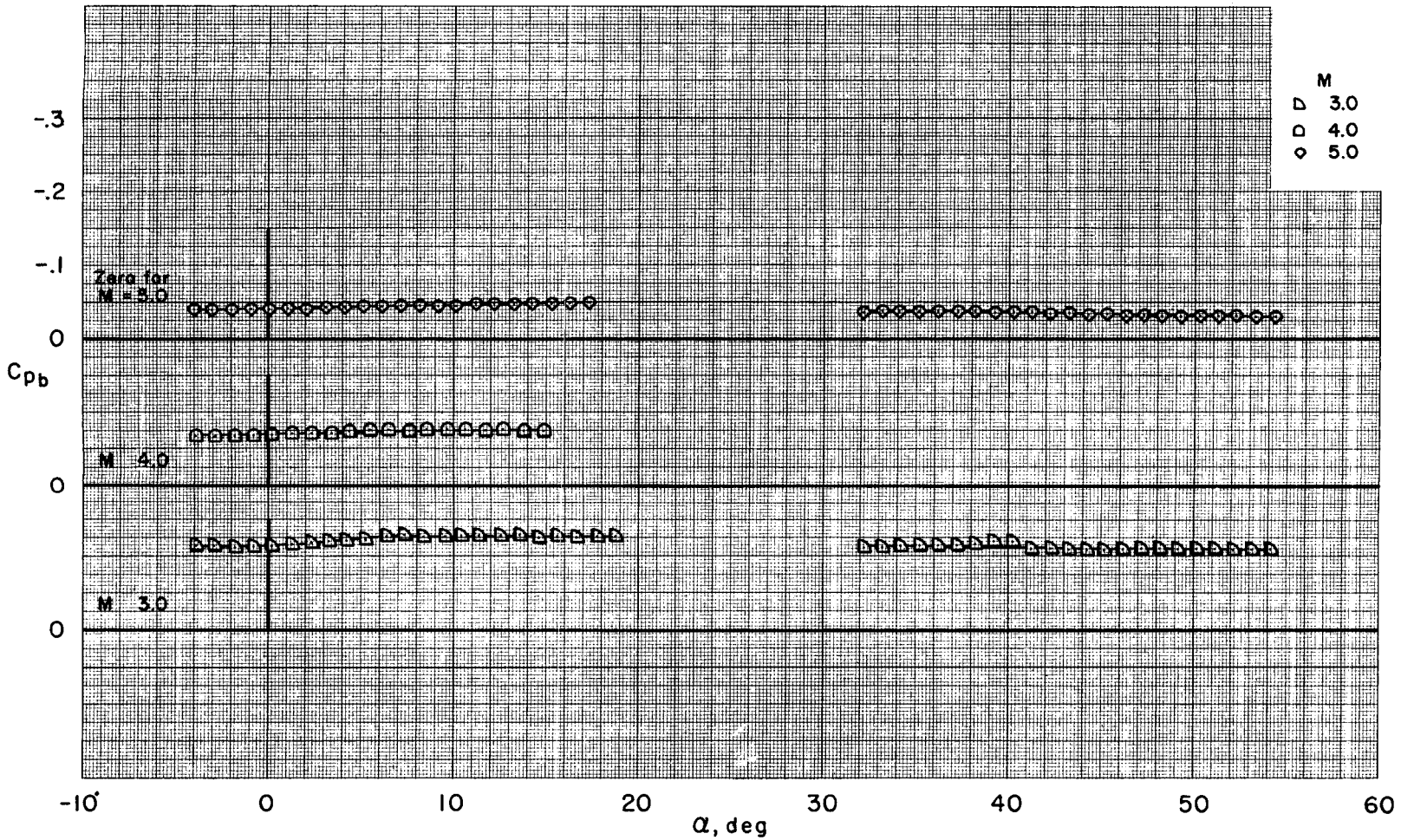
Figure 9.- Concluded.



(a) Transonic speeds.

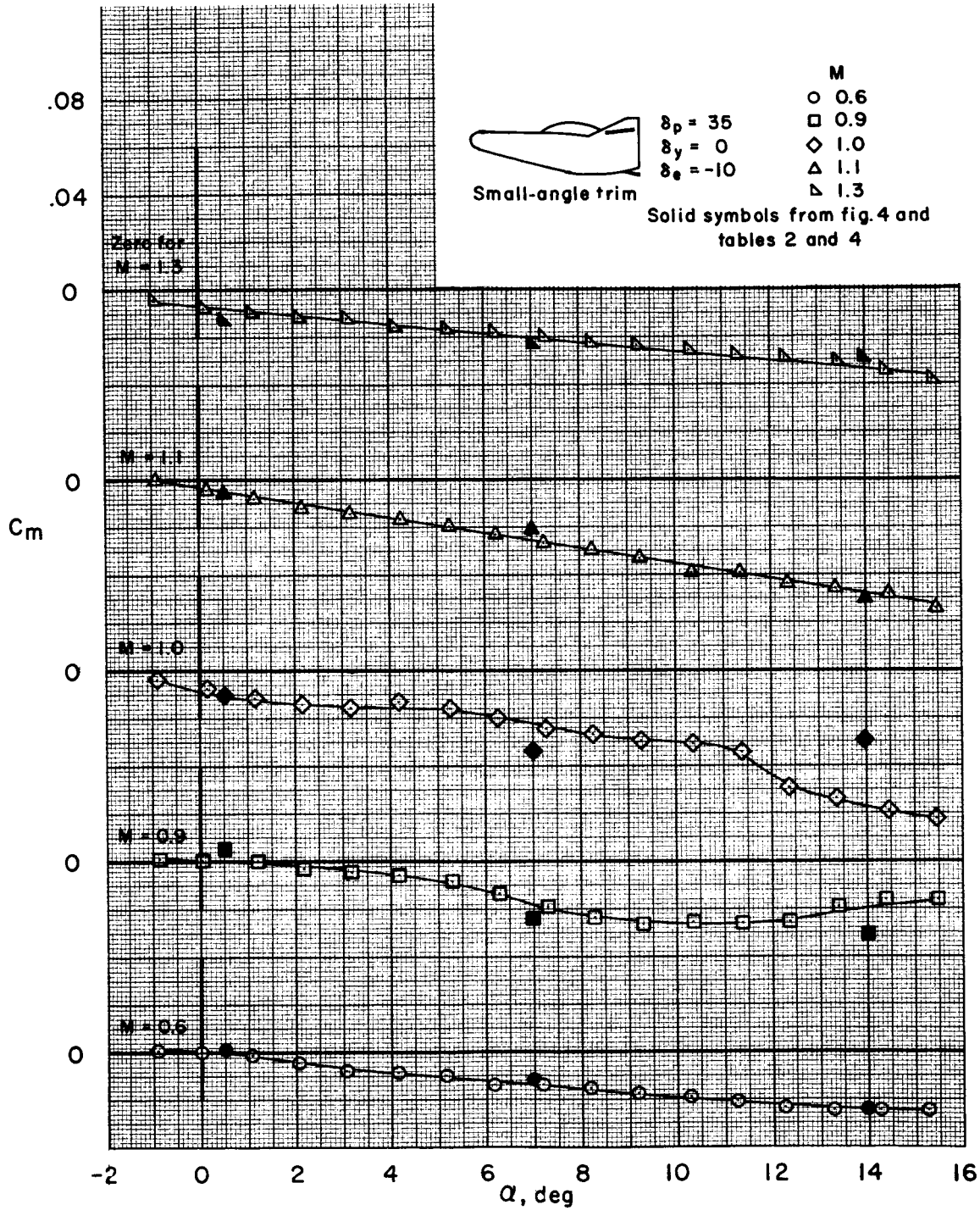
Figure 10.- Base-pressure coefficient of clean configuration (δ_p=0, δ_y=0, elevons off).

A 4 8 6



(b) Supersonic speeds.

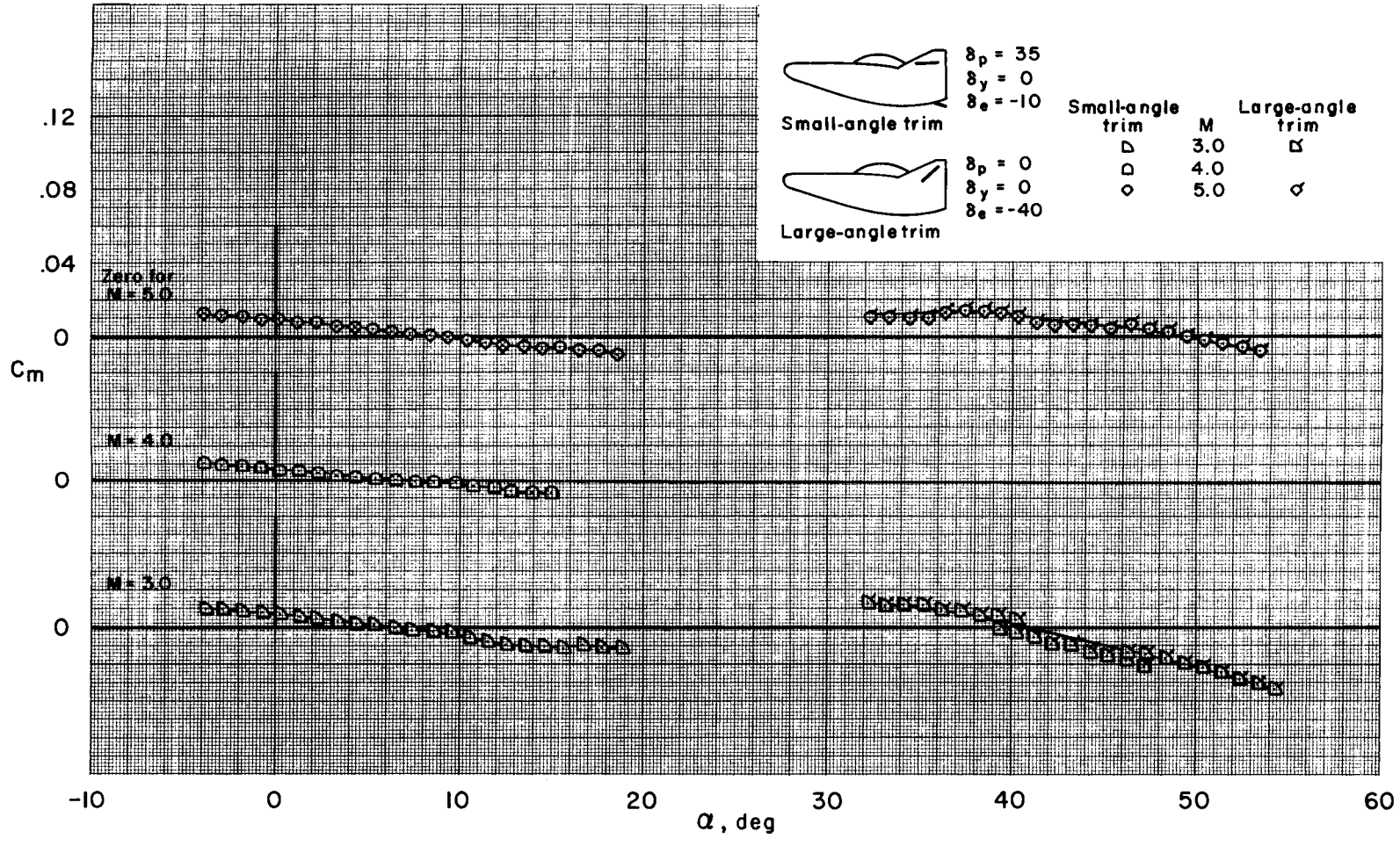
Figure 10.- Concluded.



(a) Transonic speeds.

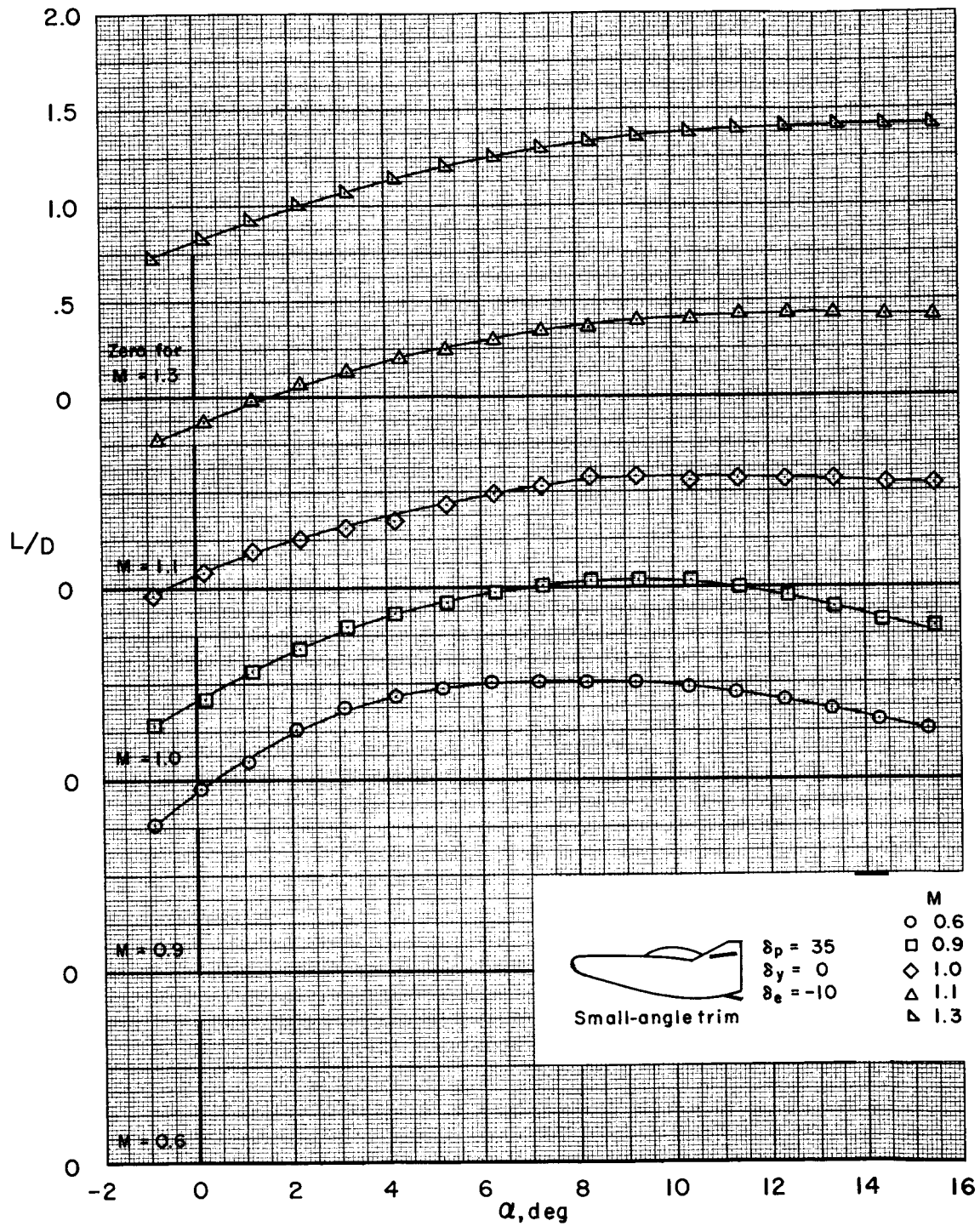
Figure 11.- Pitching moment of trimmed configurations.

A486



(b) Supersonic speeds.

Figure 11.- Concluded.



(a) Transonic speeds.

Figure 12.- Lift-drag ratio of trimmed configurations.

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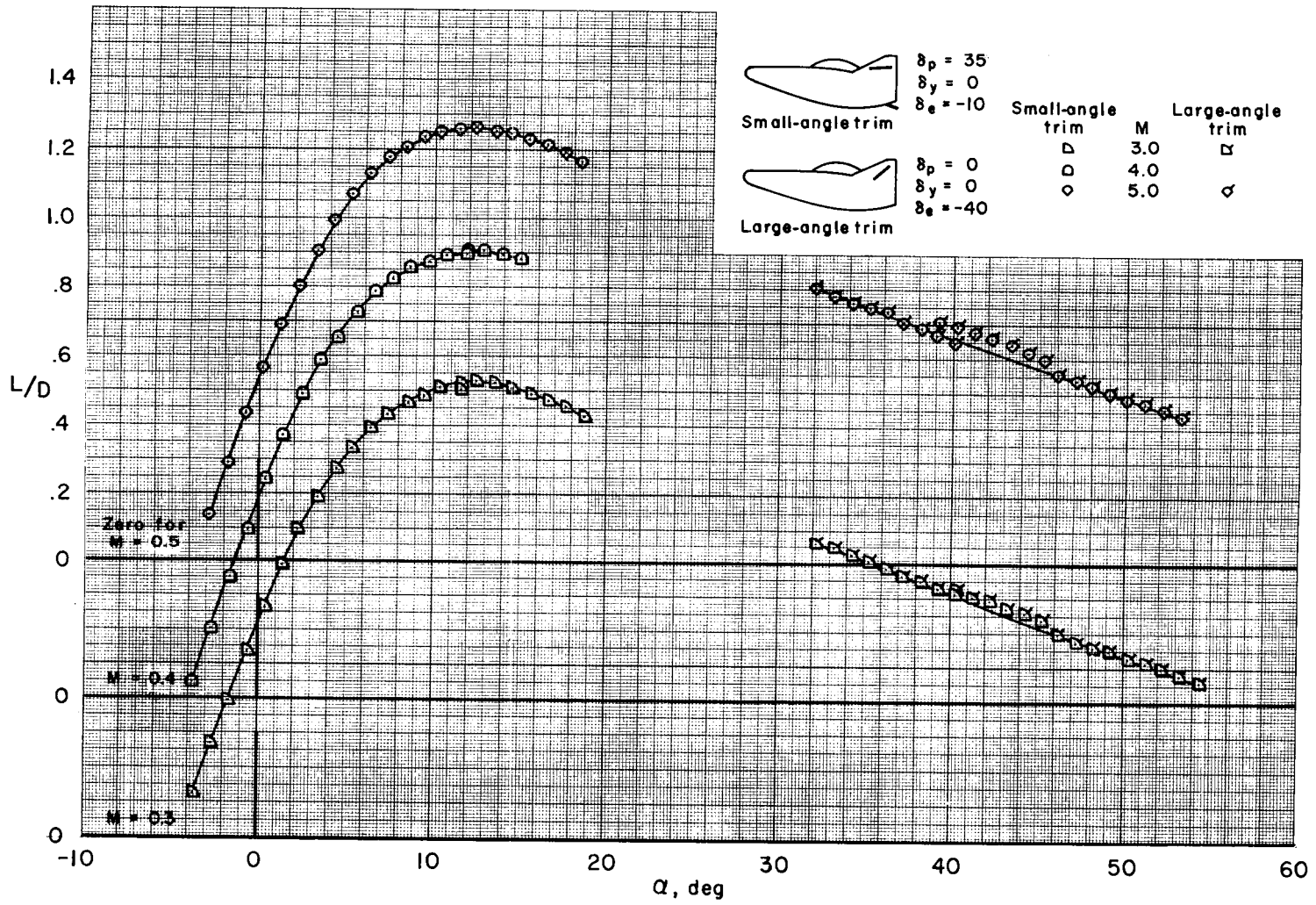
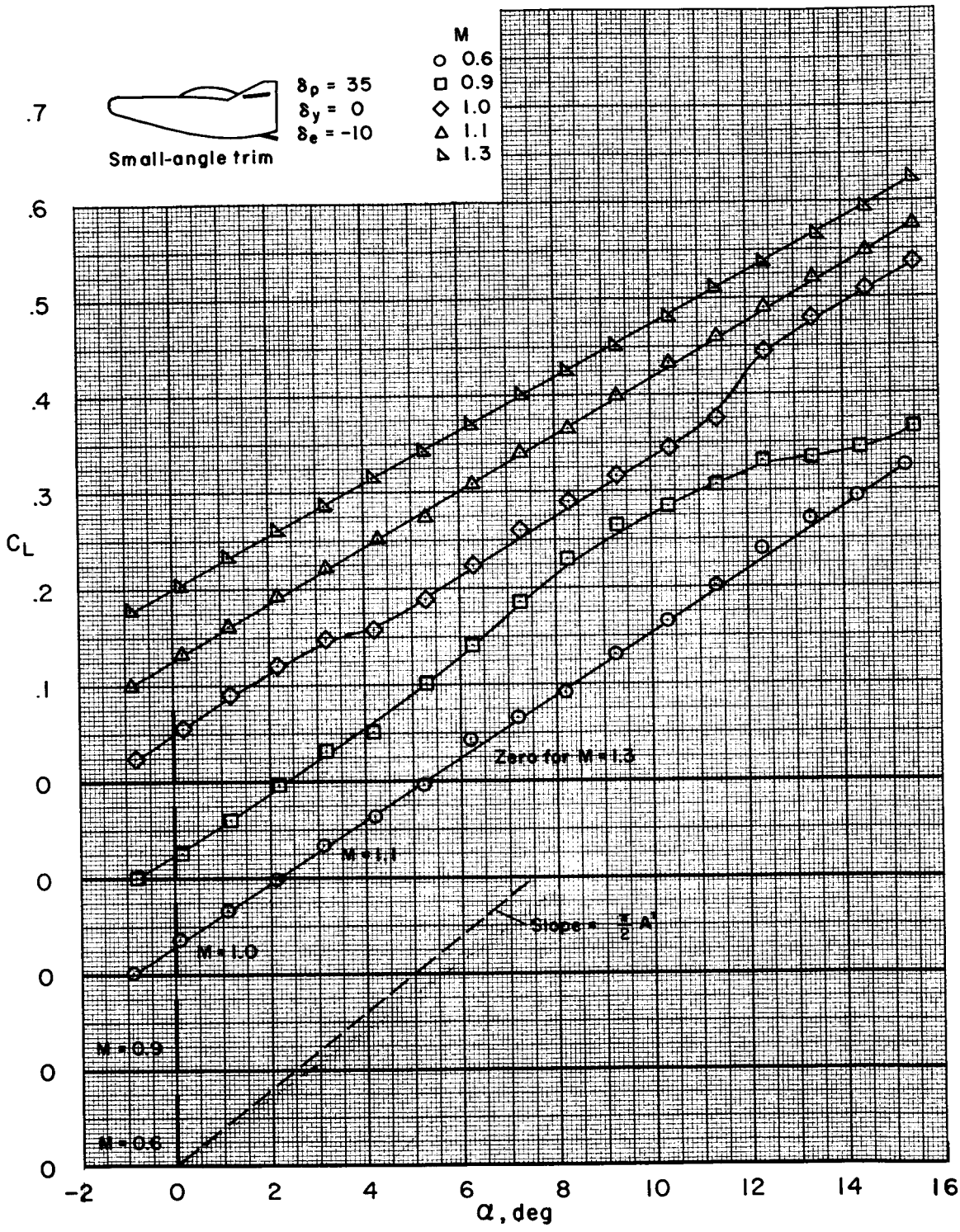


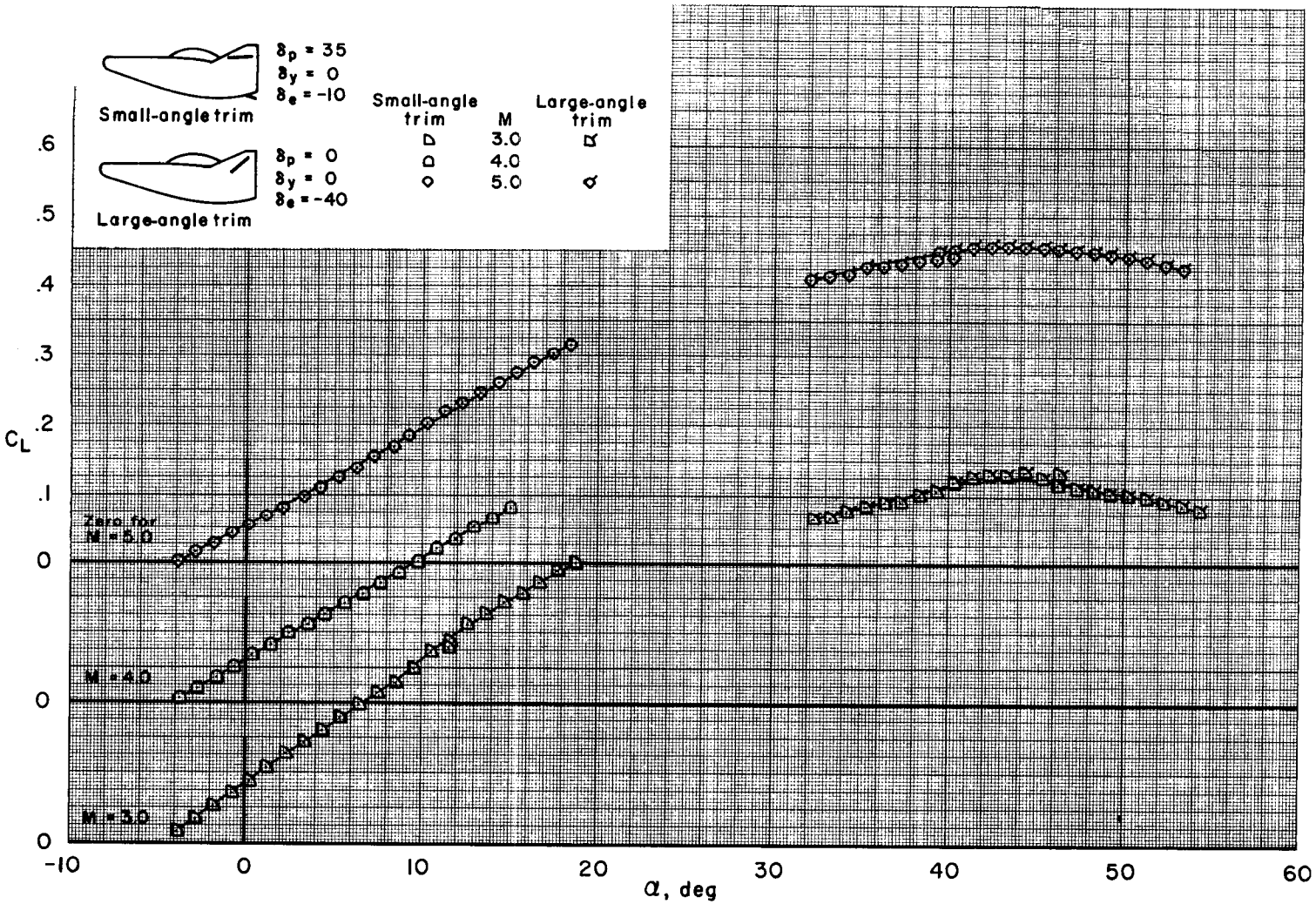
(b) Supersonic speeds.

Figure 12.- Concluded.



(a) Transonic speeds.

Figure 13.- Lift coefficient of trimmed configurations.



(b) Supersonic speeds.

Figure 13.- Concluded.

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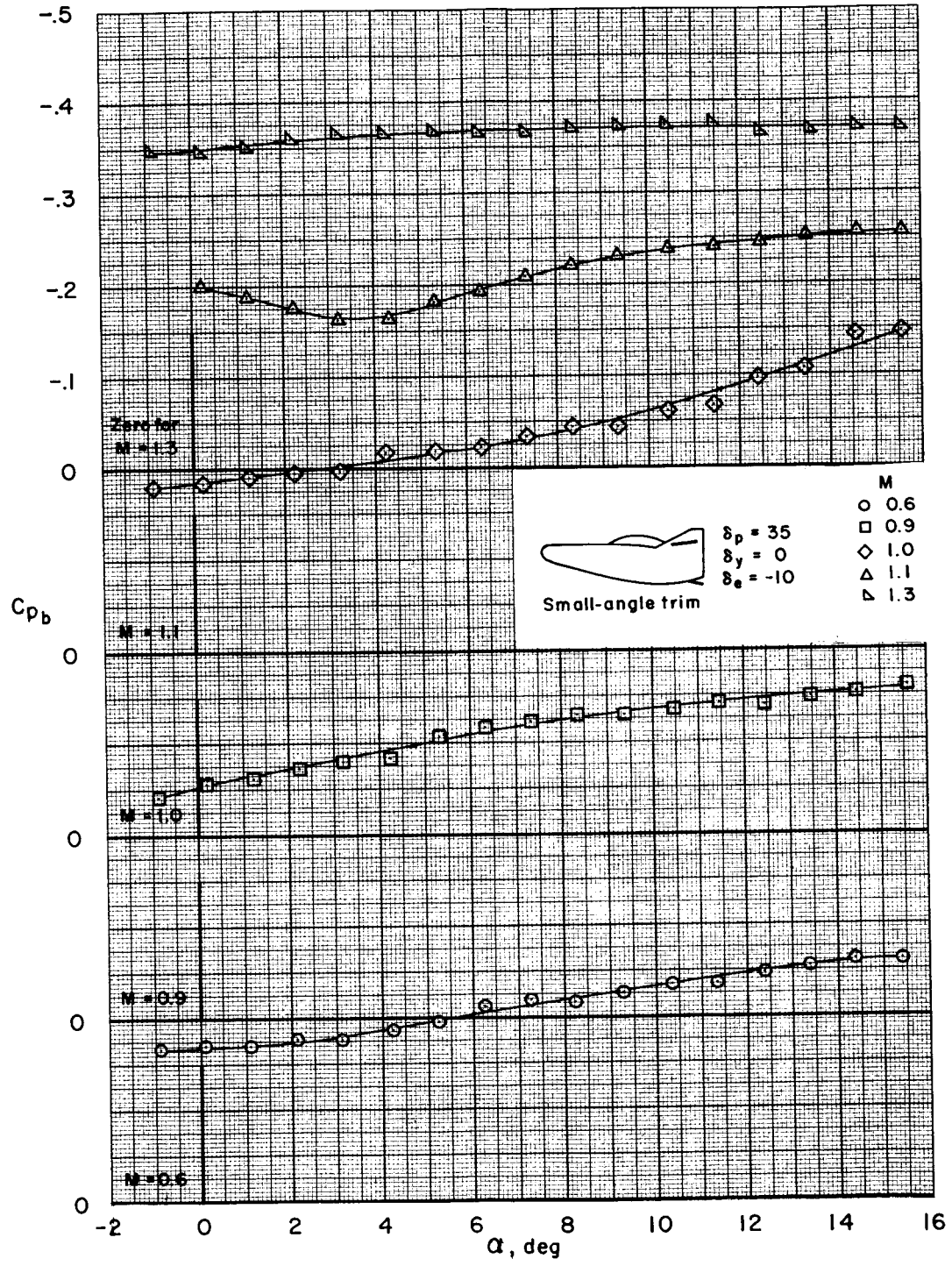

(a) Transonic speeds.

Figure 14.- Base-pressure coefficient of trimmed configurations.

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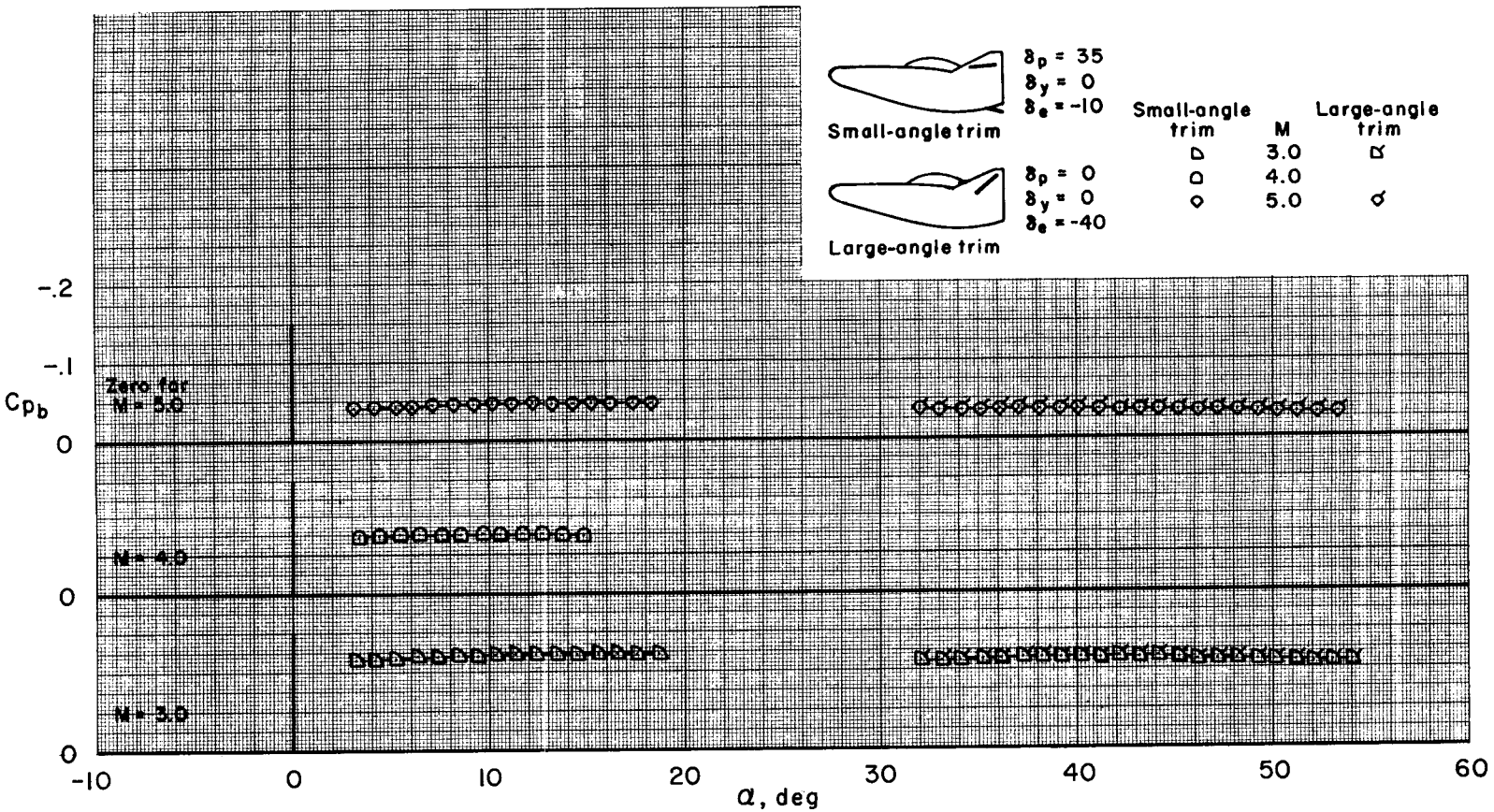
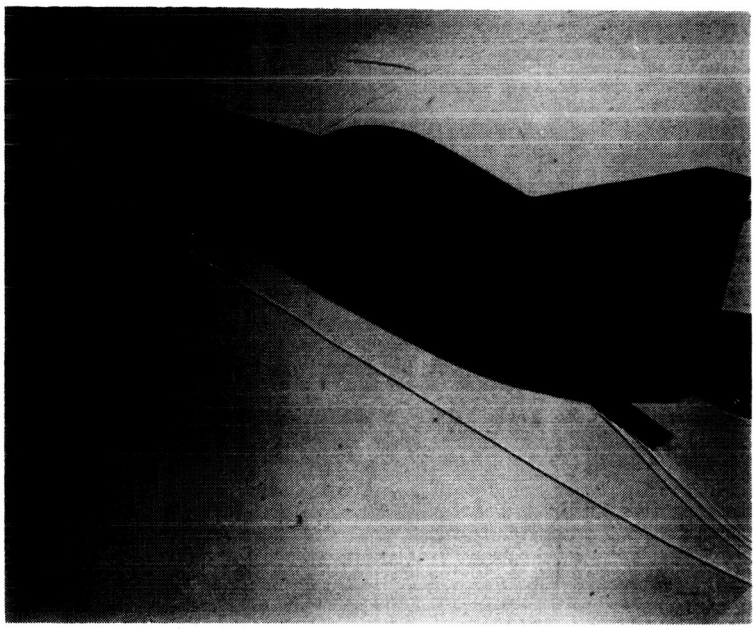
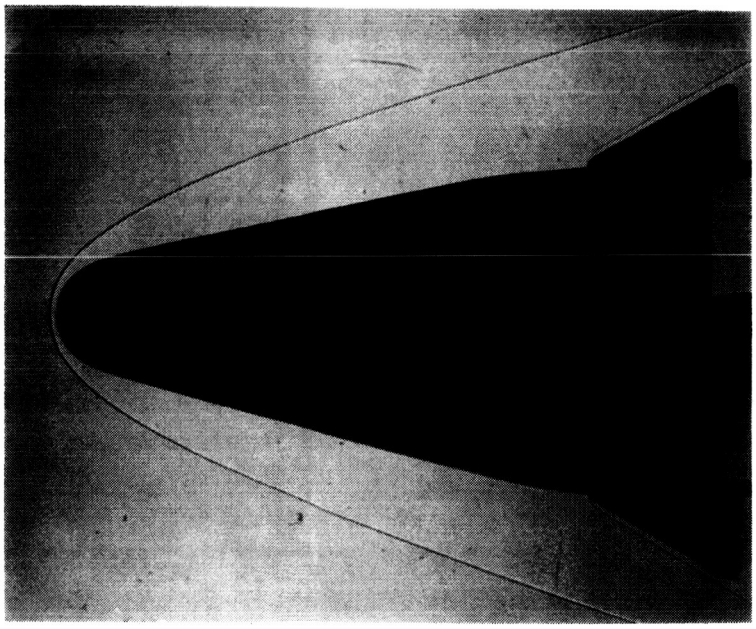


(b) Supersonic speeds.

Figure 14.- Concluded.



Side view.



Bottom view.

(a) Configuration for small-angle trim (α=14°).

Figure 15.- Shadowgraphs of flow at M = 5.0.

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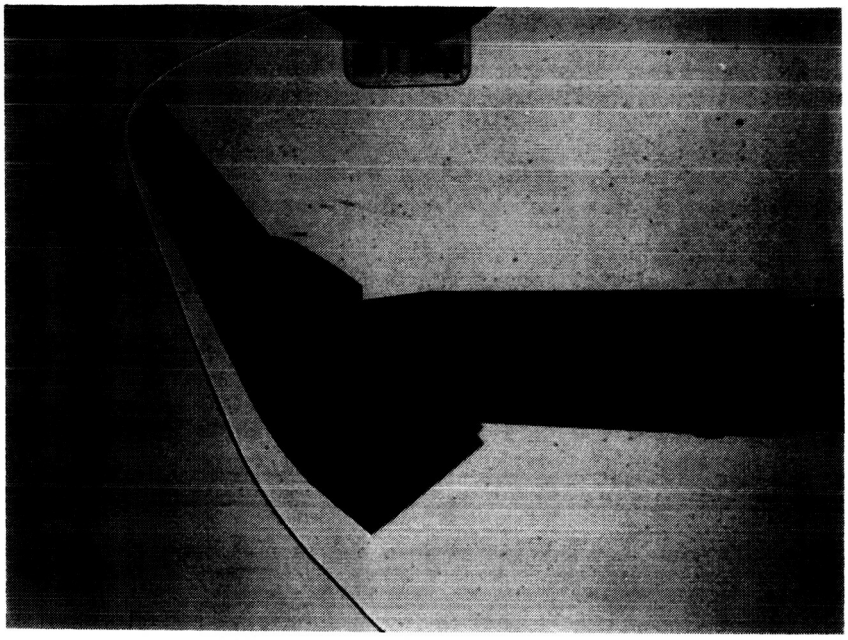
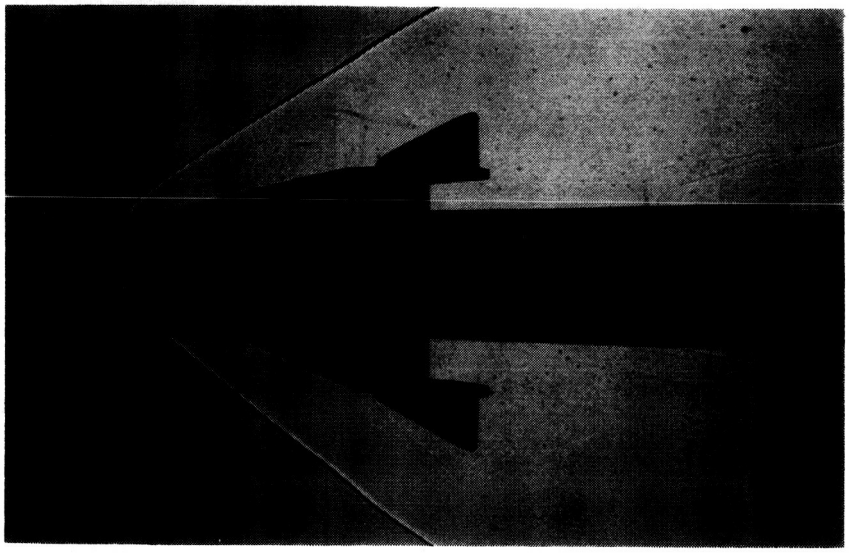


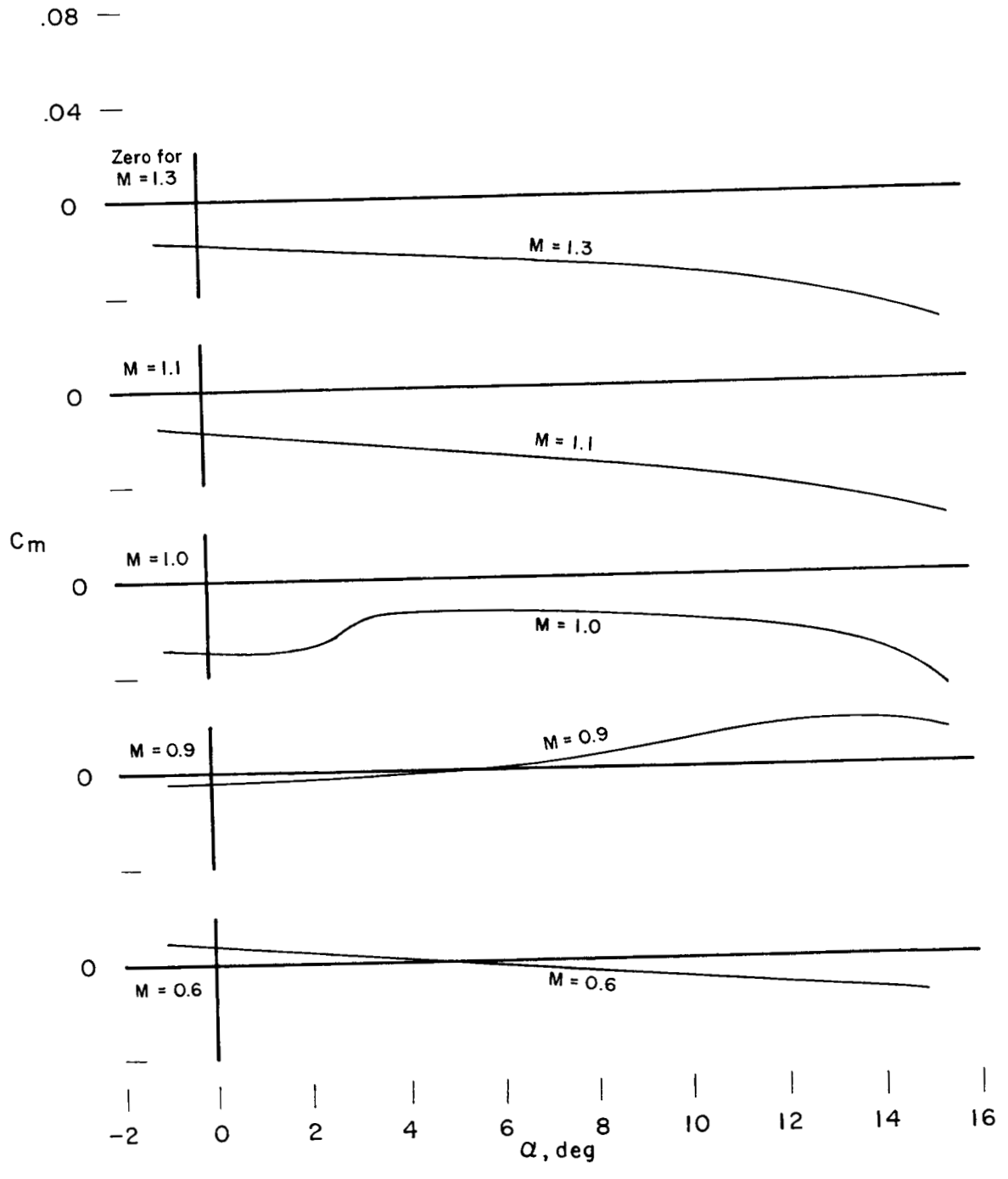
Side view.



Bottom view.

(b) Configuration for large-angle trim (α=50°).

Figure 15.- Concluded.



(a) Transonic speeds.

Figure 16.- Pitching-moment coefficient of the clean configurations with moment center at $x/l = 0.45$.

A
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6

A
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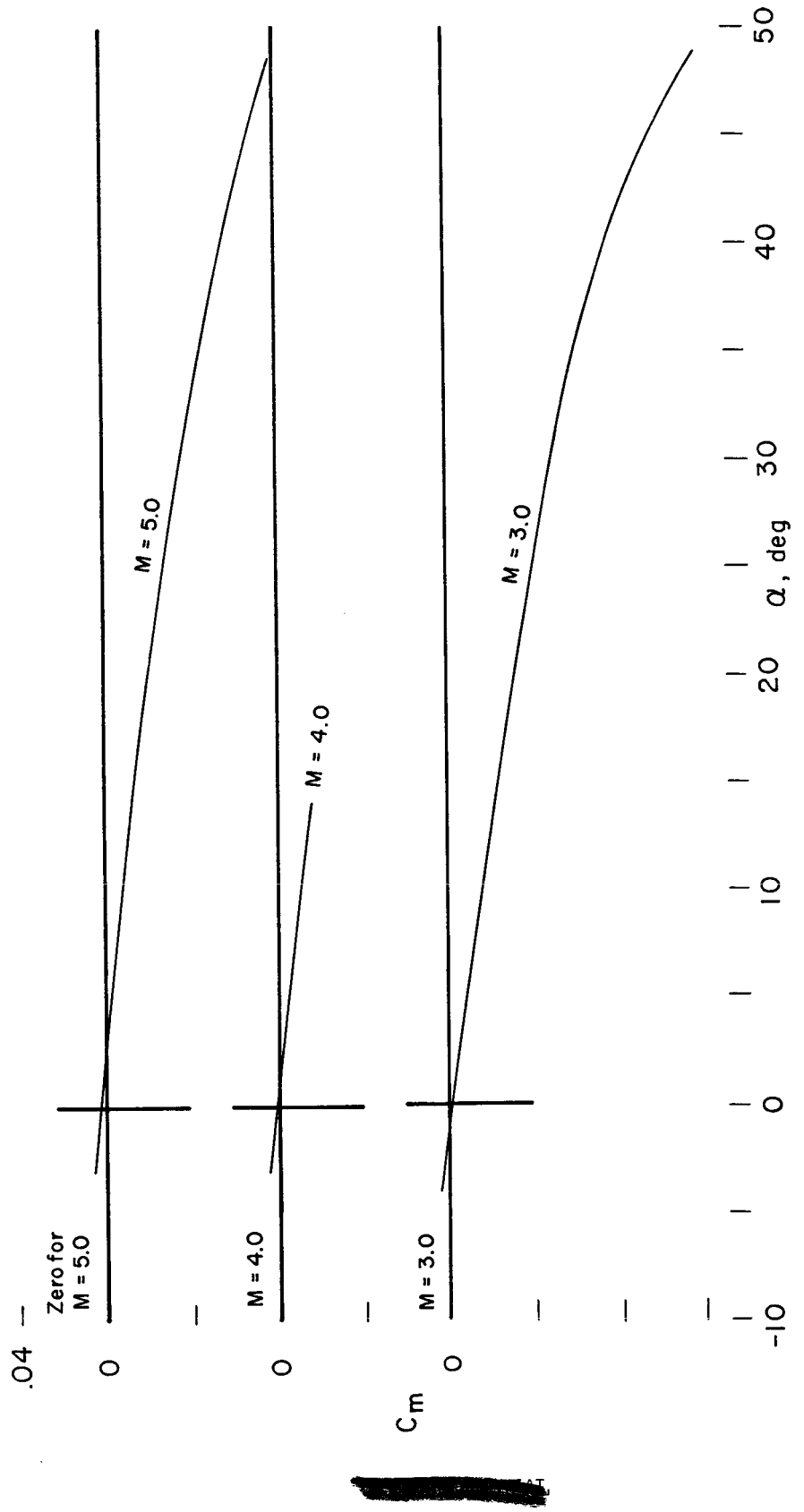
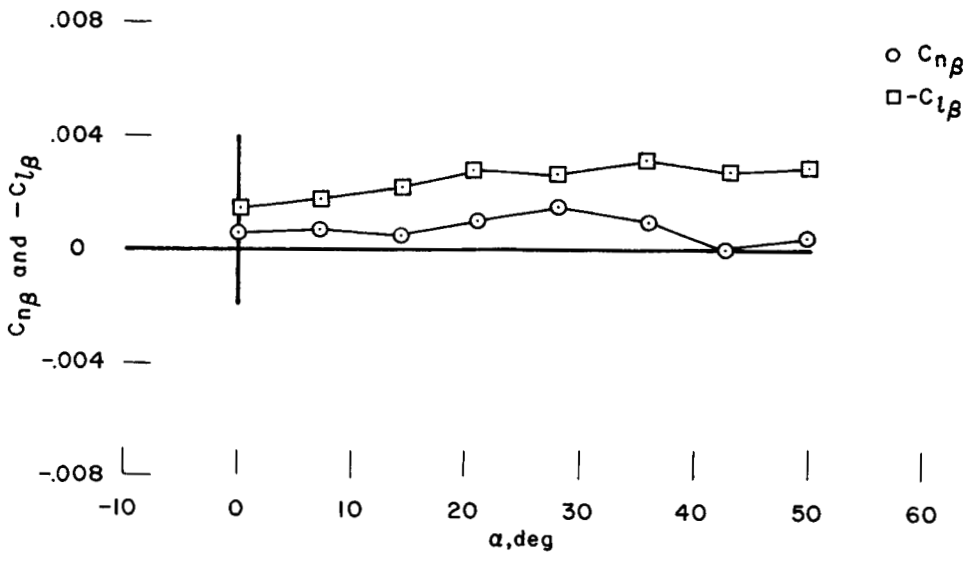
6
4
4

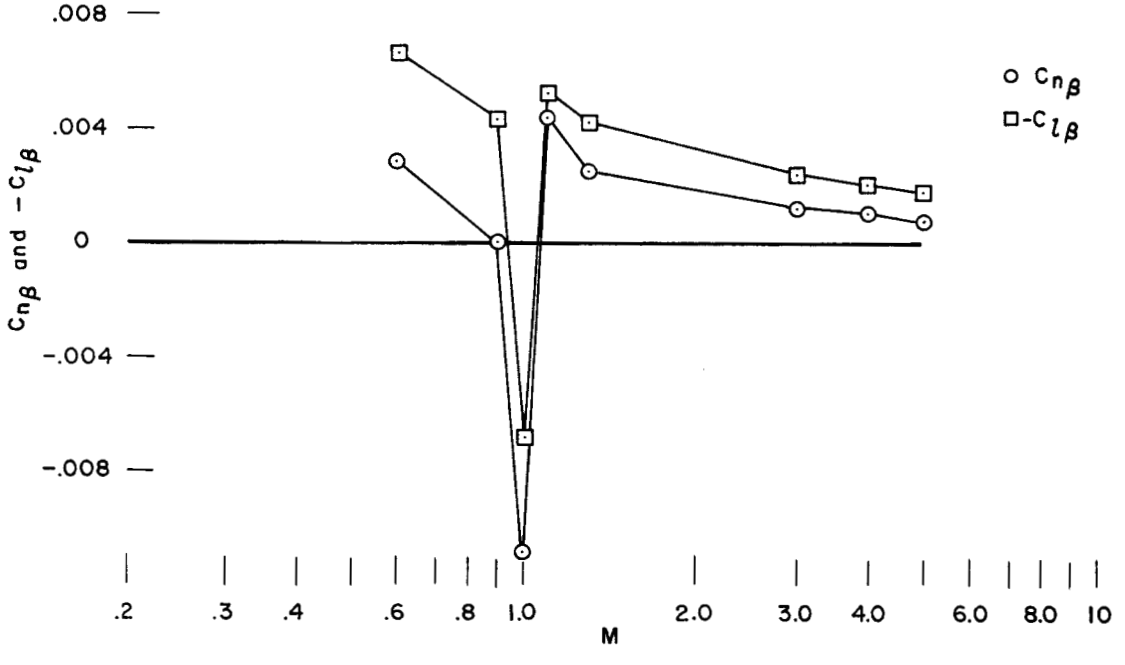


(b) Supersonic speeds.

Figure 16.- Concluded.



(a) Variation with angle of attack at M = 5.0.



(b) Variation with Mach number at $\alpha = 7.2^{\circ}$.

Figure 17.- Lateral-directional characteristics of clean configuration (δ_p=0, δ_y=0, elevons off).

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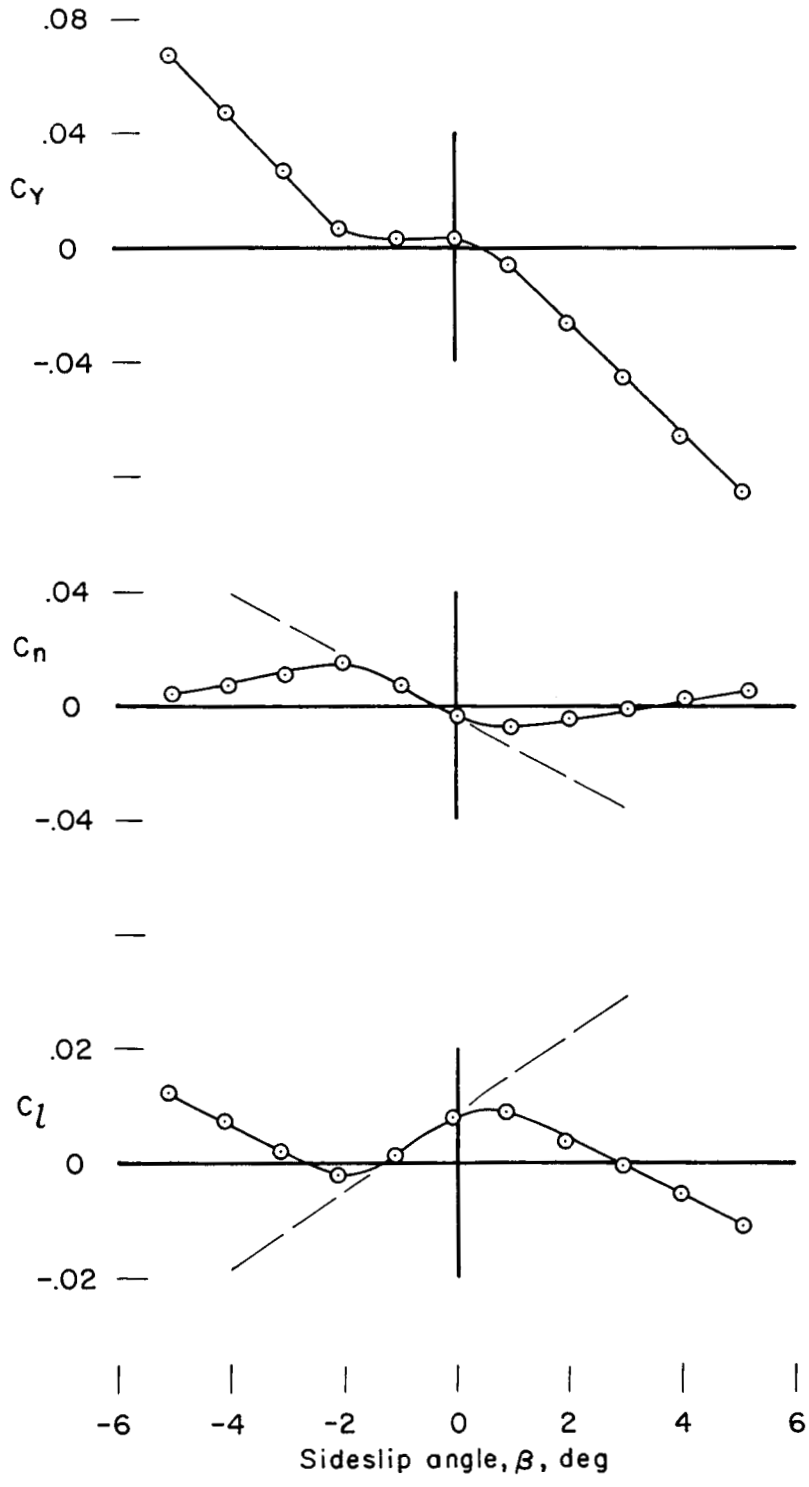


Figure 18.- Lateral-directional characteristics of clean configuration at M=1.0, α=7.2° (δ_p=0, δ_y=0, elevons off).

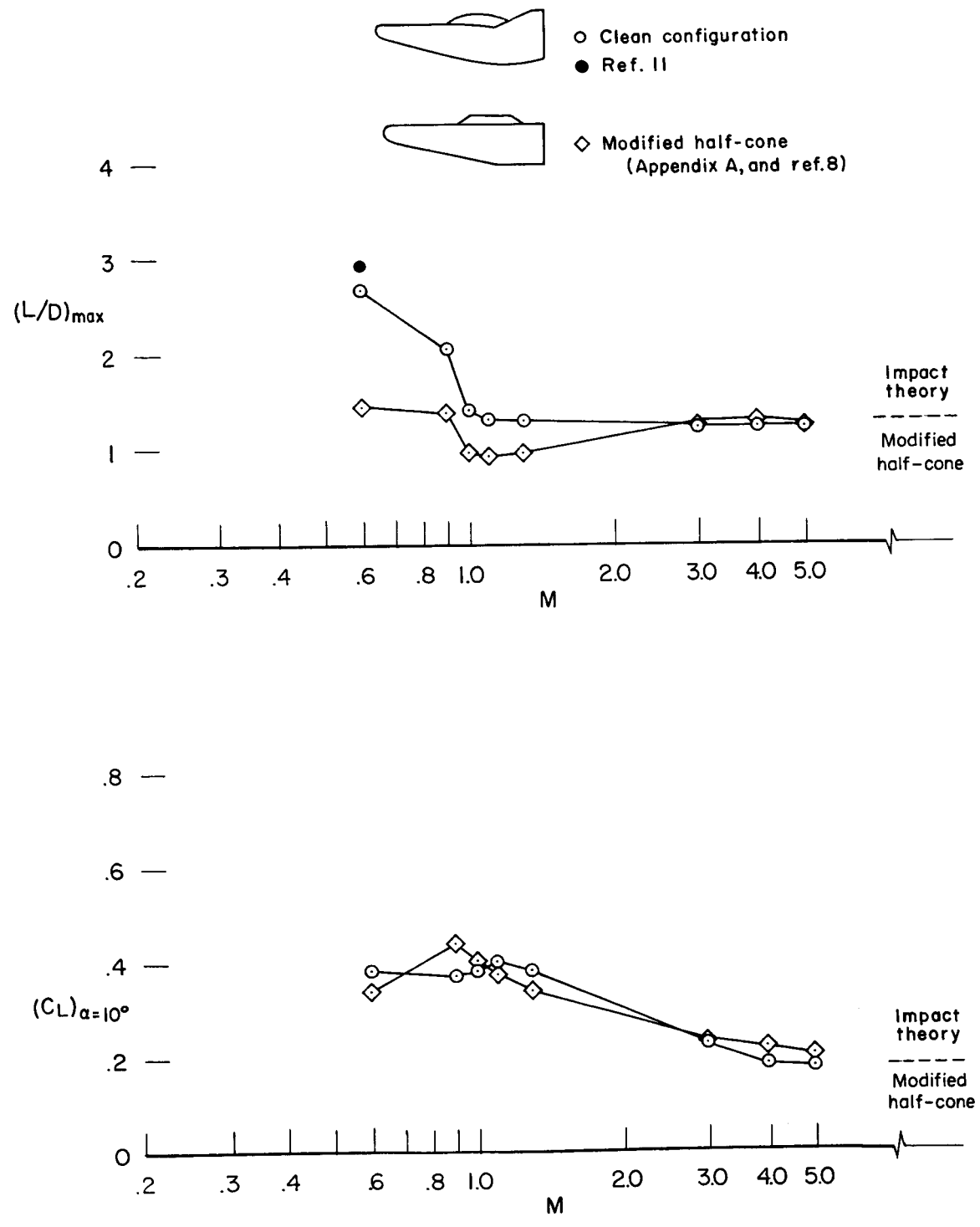


Figure 19.- Performance of clean configuration.

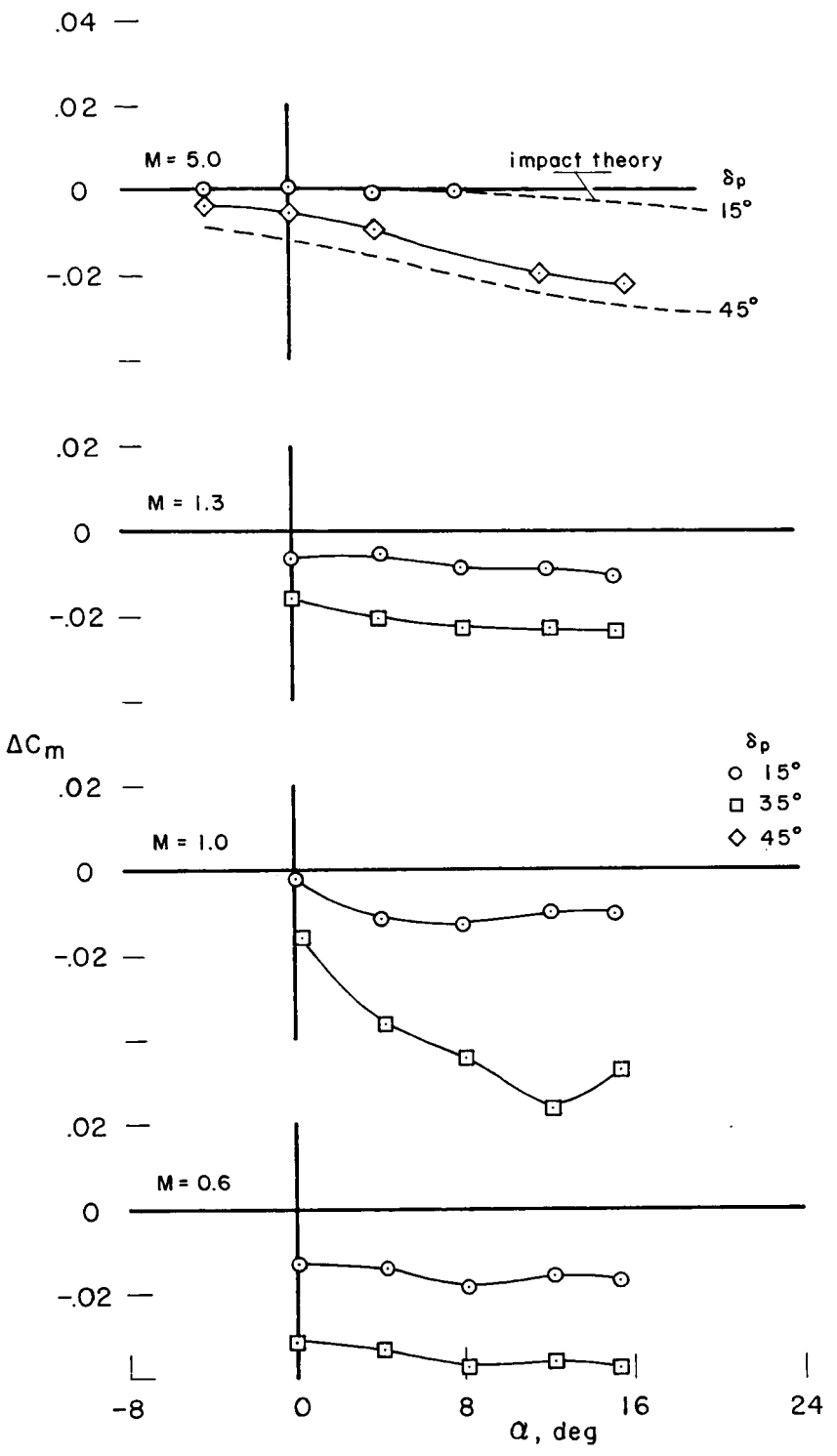
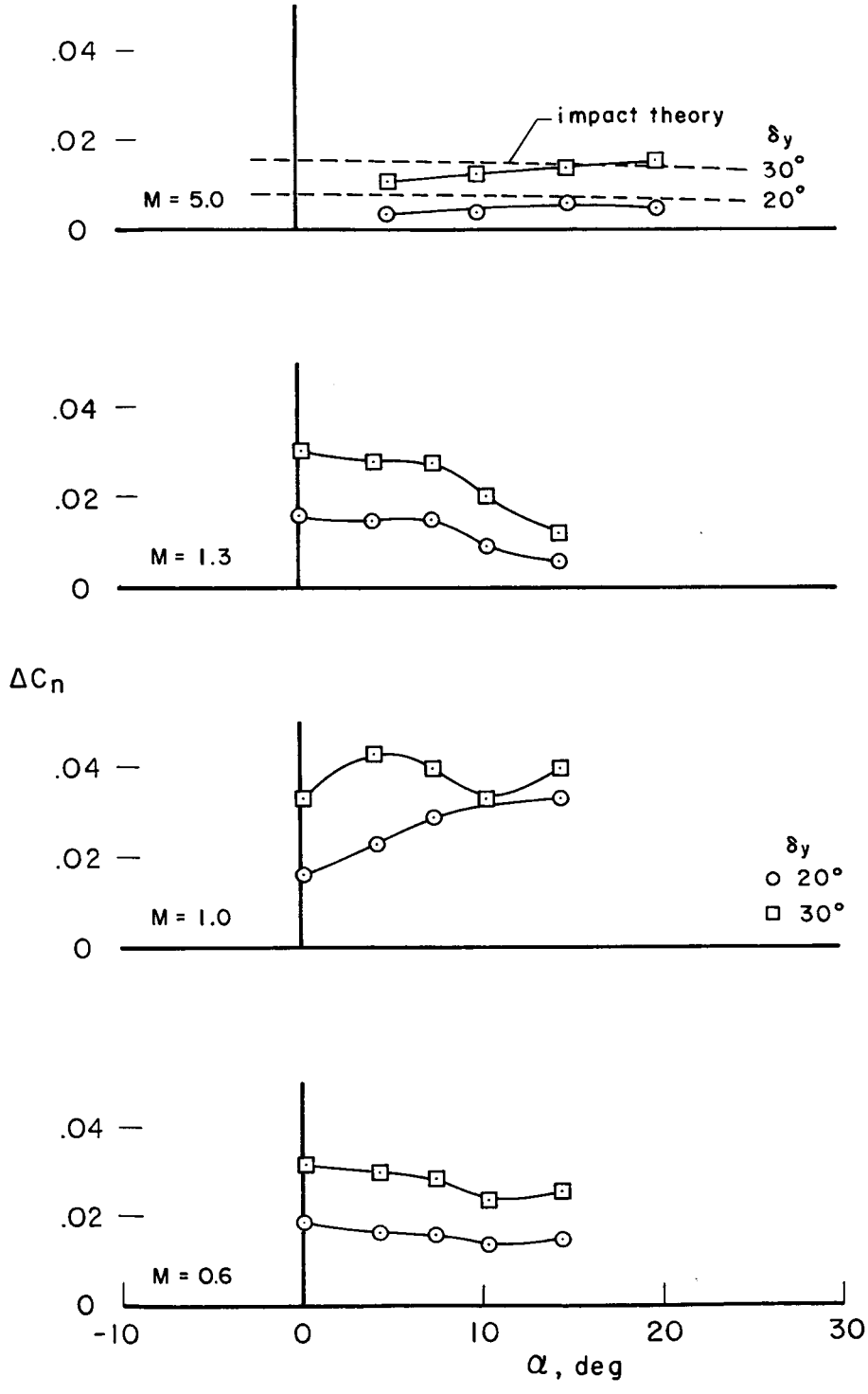


Figure 20.- Typical pitch flap characteristics (both flaps deflected).

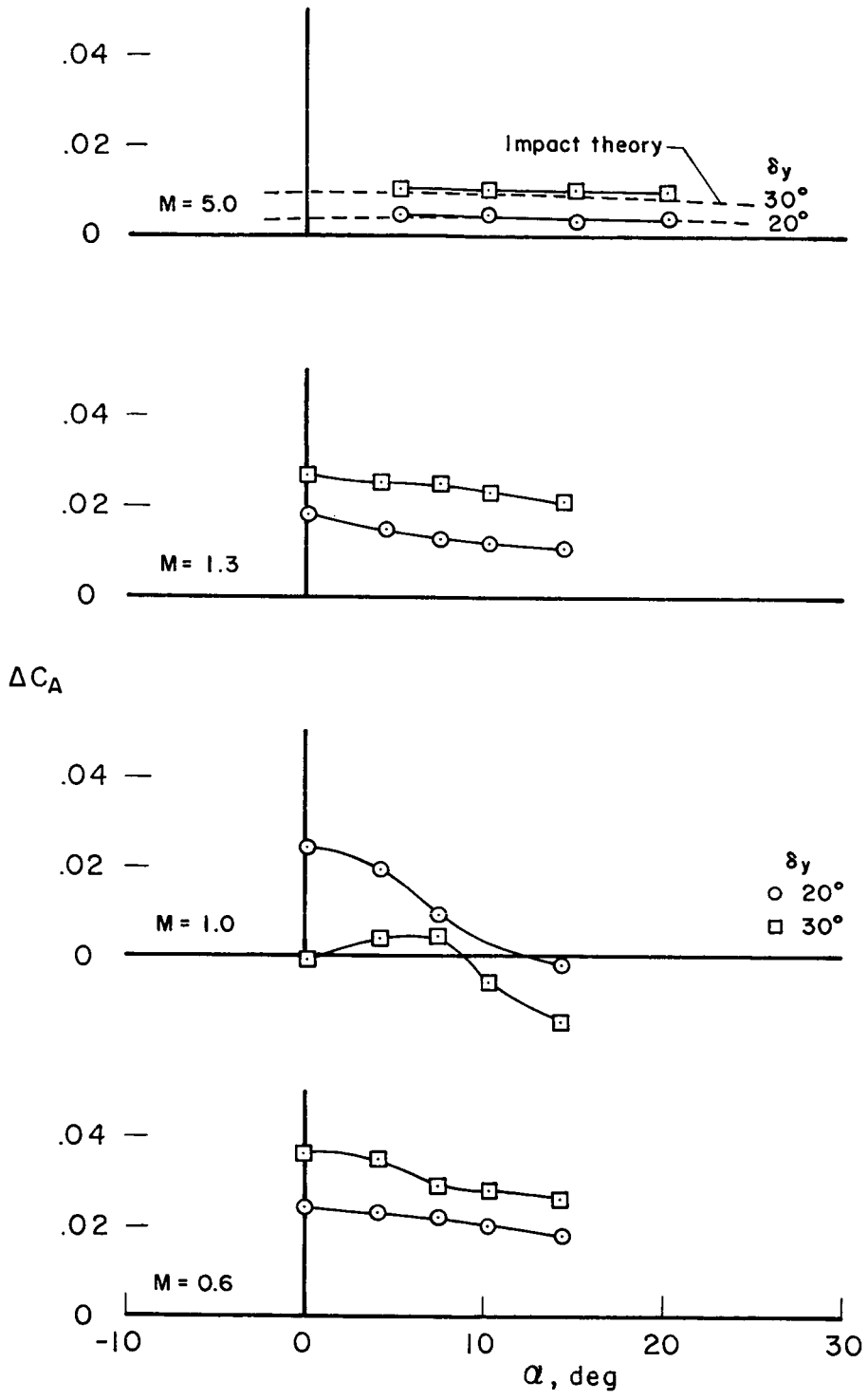
A 4 8 6



(a) Yawing moment.

Figure 21.- Typical yaw flap characteristics.

A 4 8 6



(b) Axial force.

Figure 21.- Concluded.

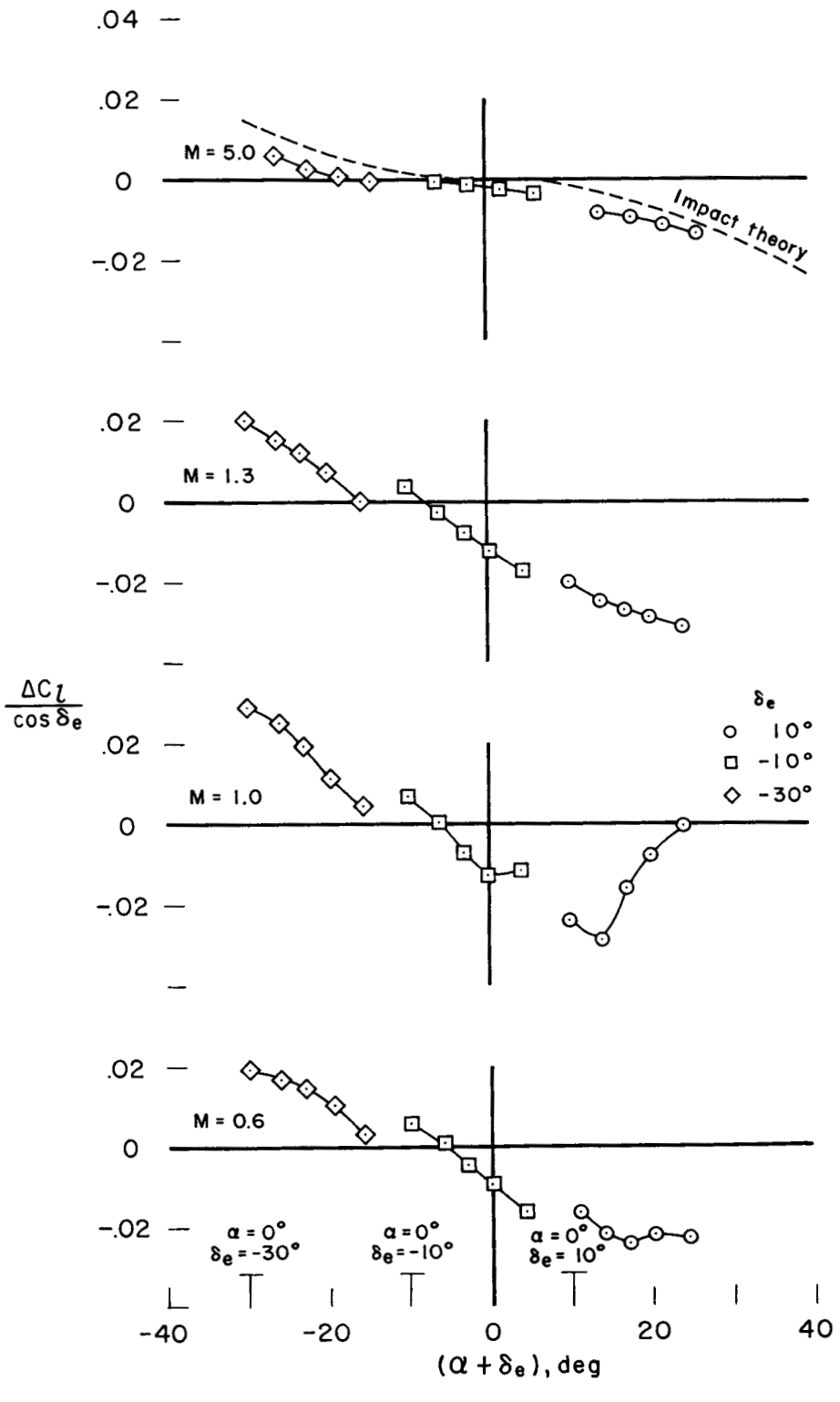


Figure 22.- Typical elevon characteristics.

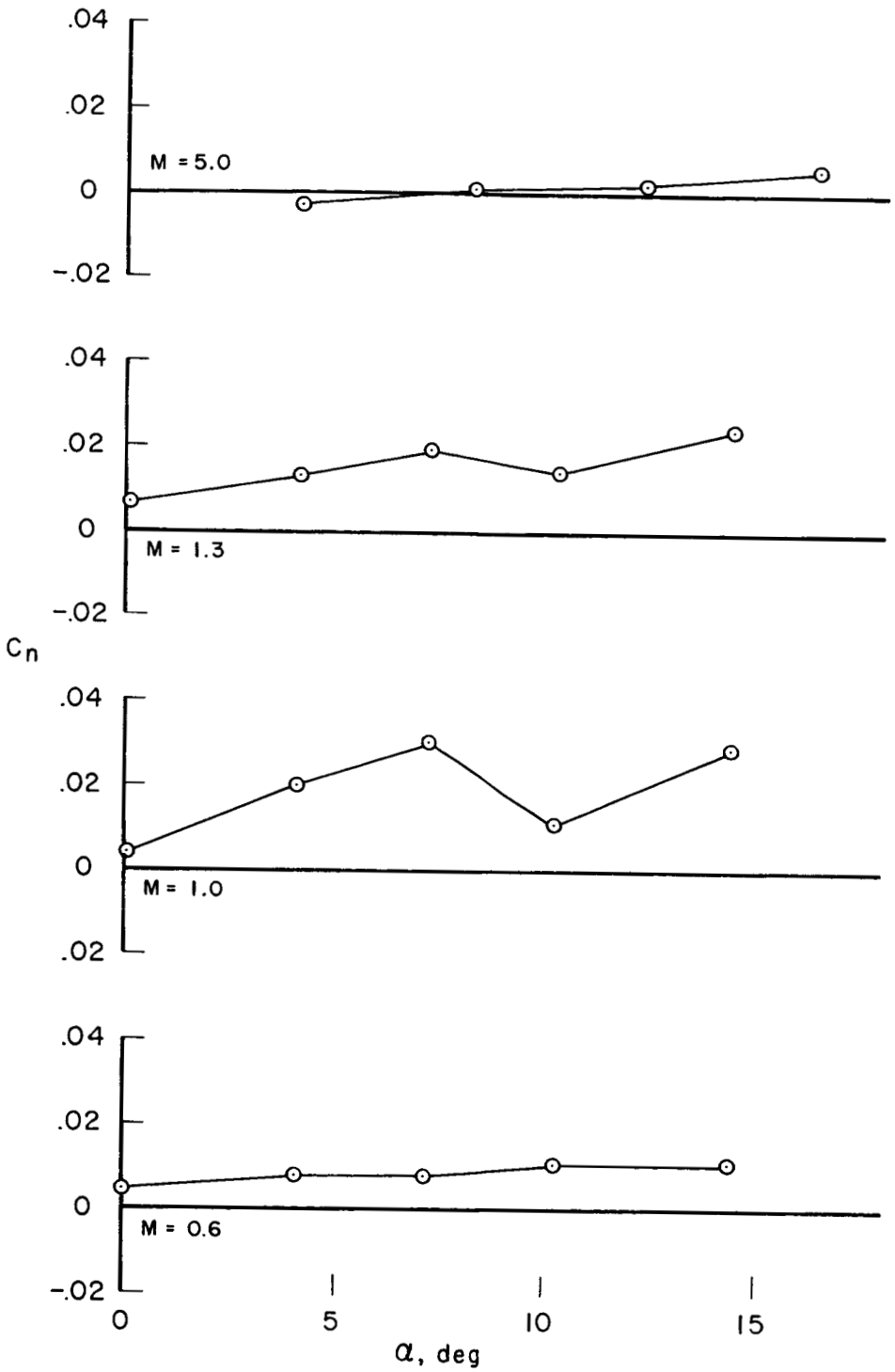


Figure 23.- Net yawing moment due to the elevons for right elevon at δ_e=10° and left elevon at δ_e=-30°.

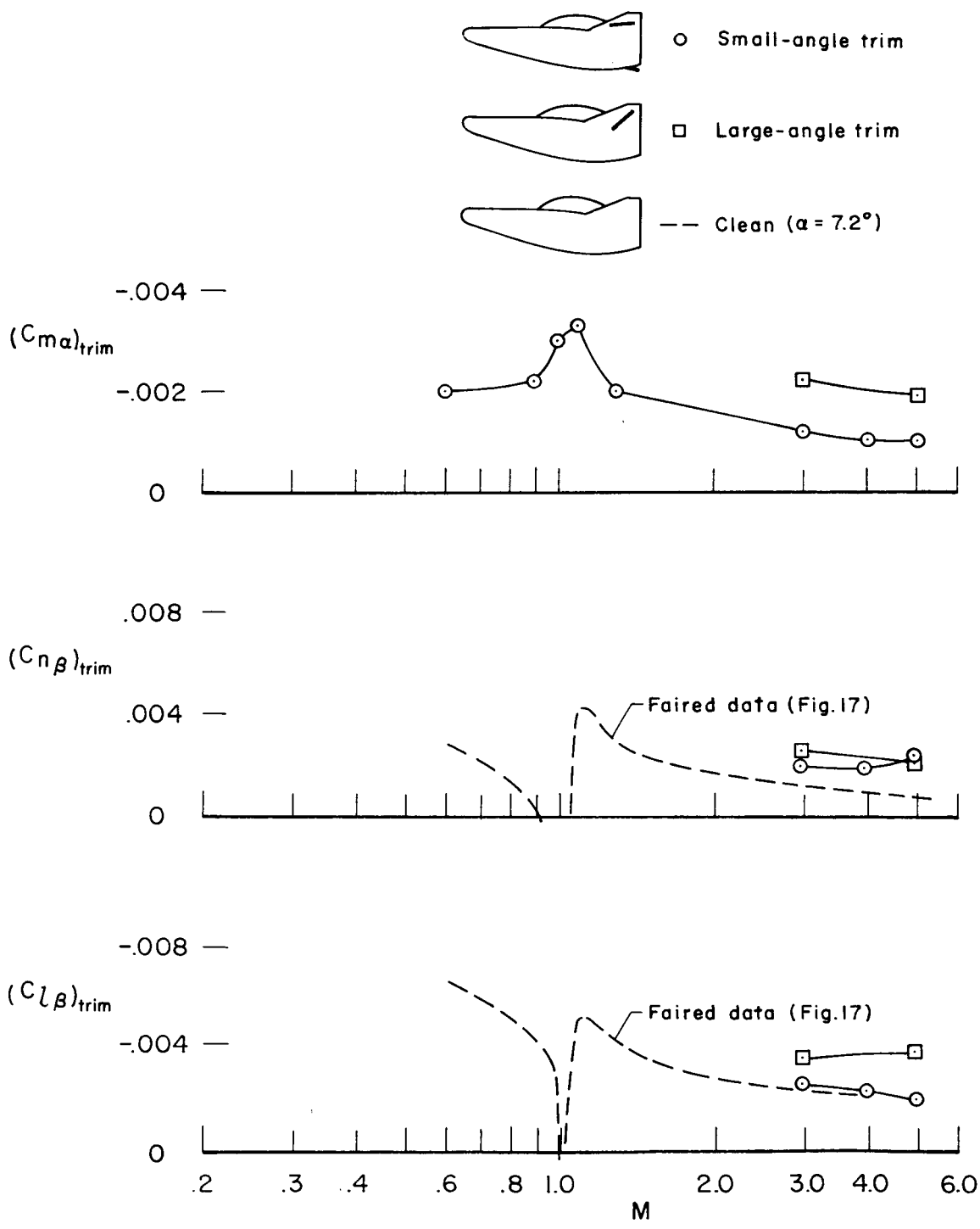


Figure 24.- Stability of trimmed configurations.

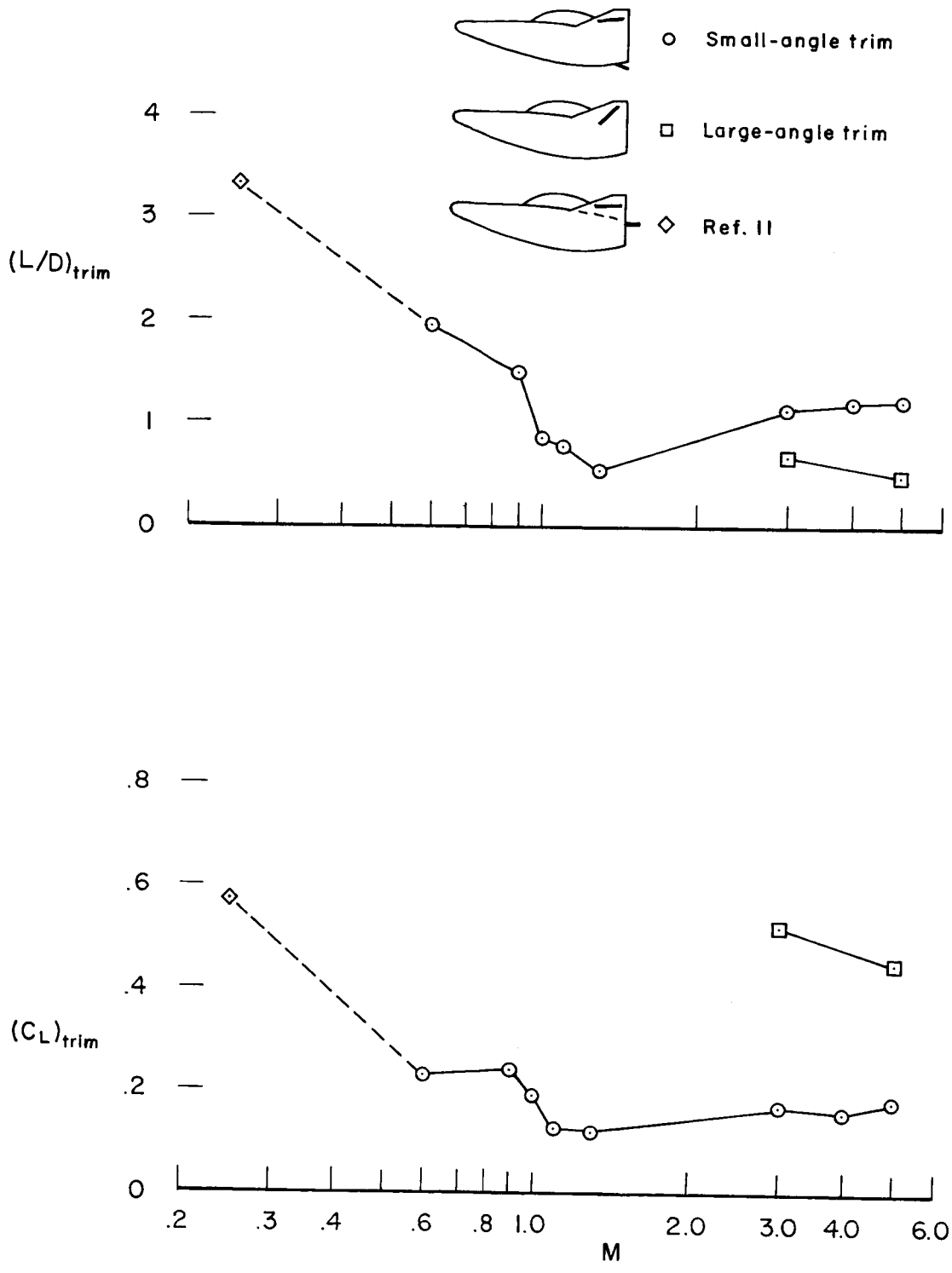


Figure 25.- Performance of trimmed configurations.

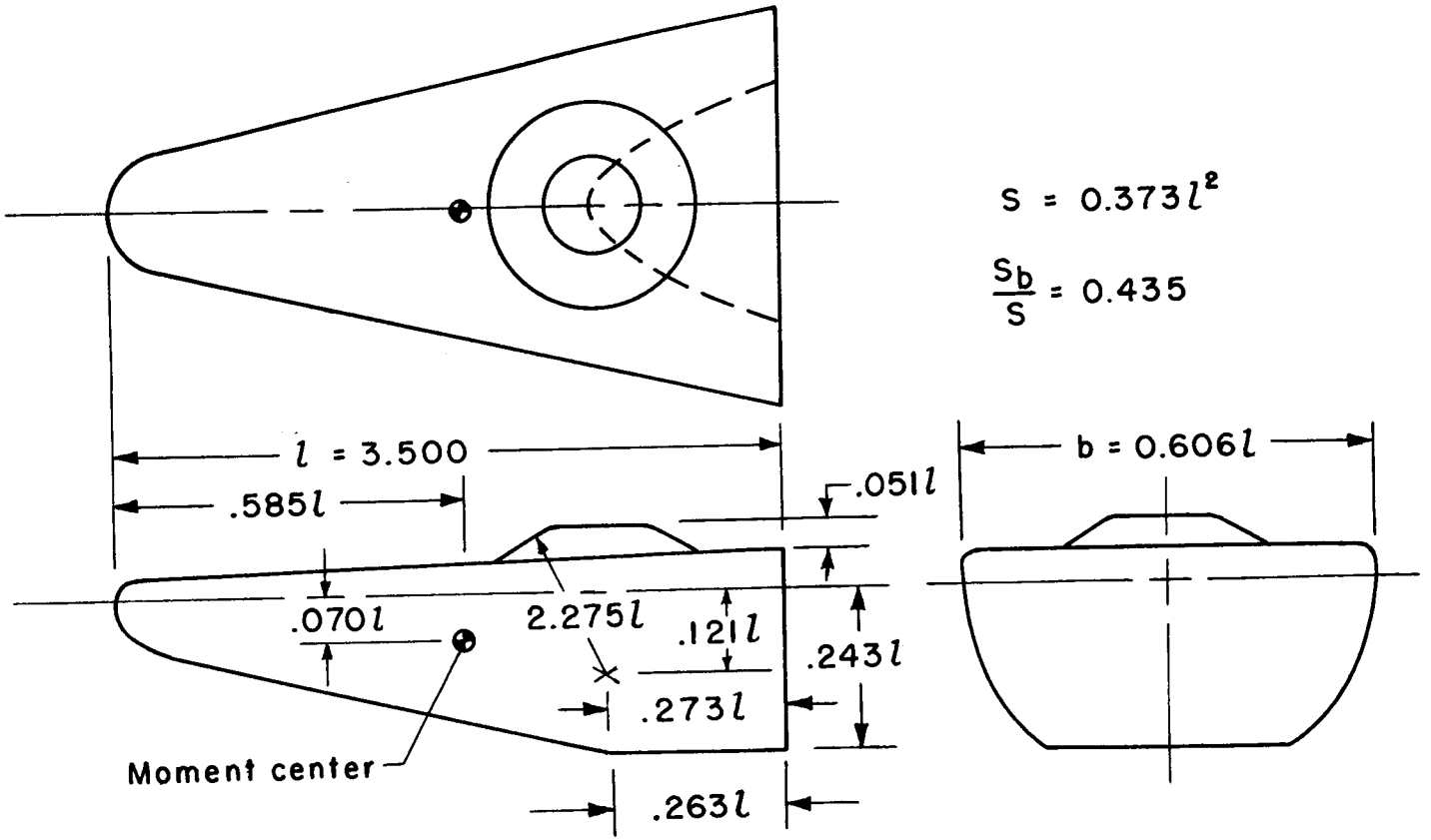


Figure 26.- Geometry of a modified 13° half-cone model (cf. ref. 8).

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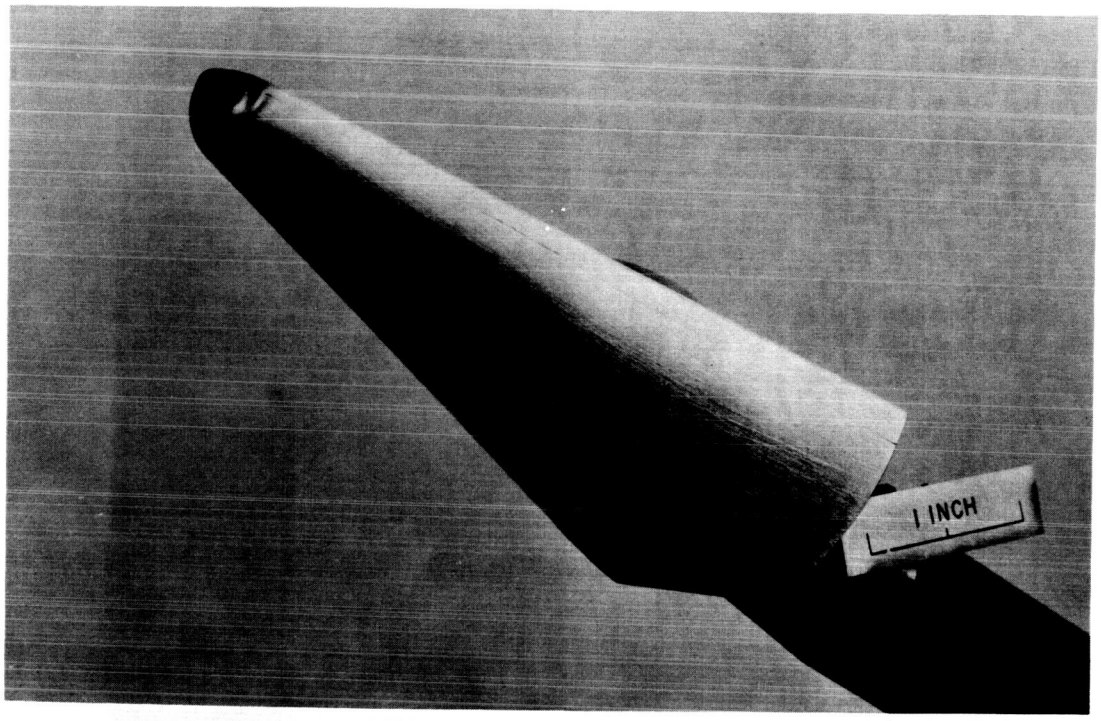

A-26827

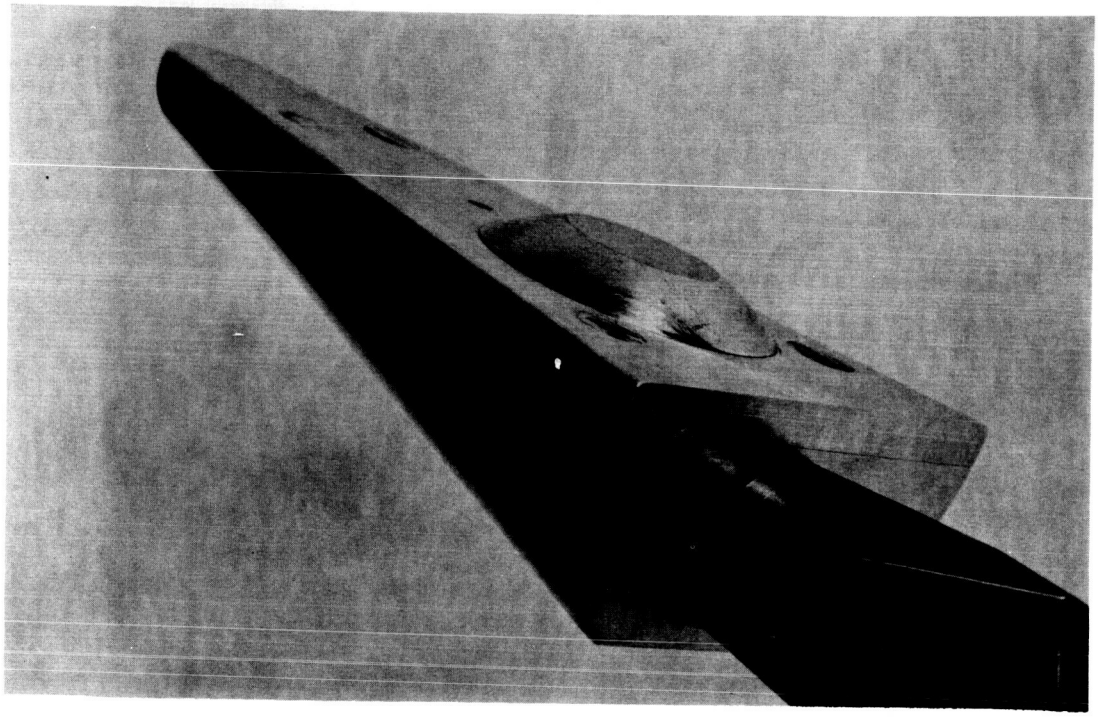

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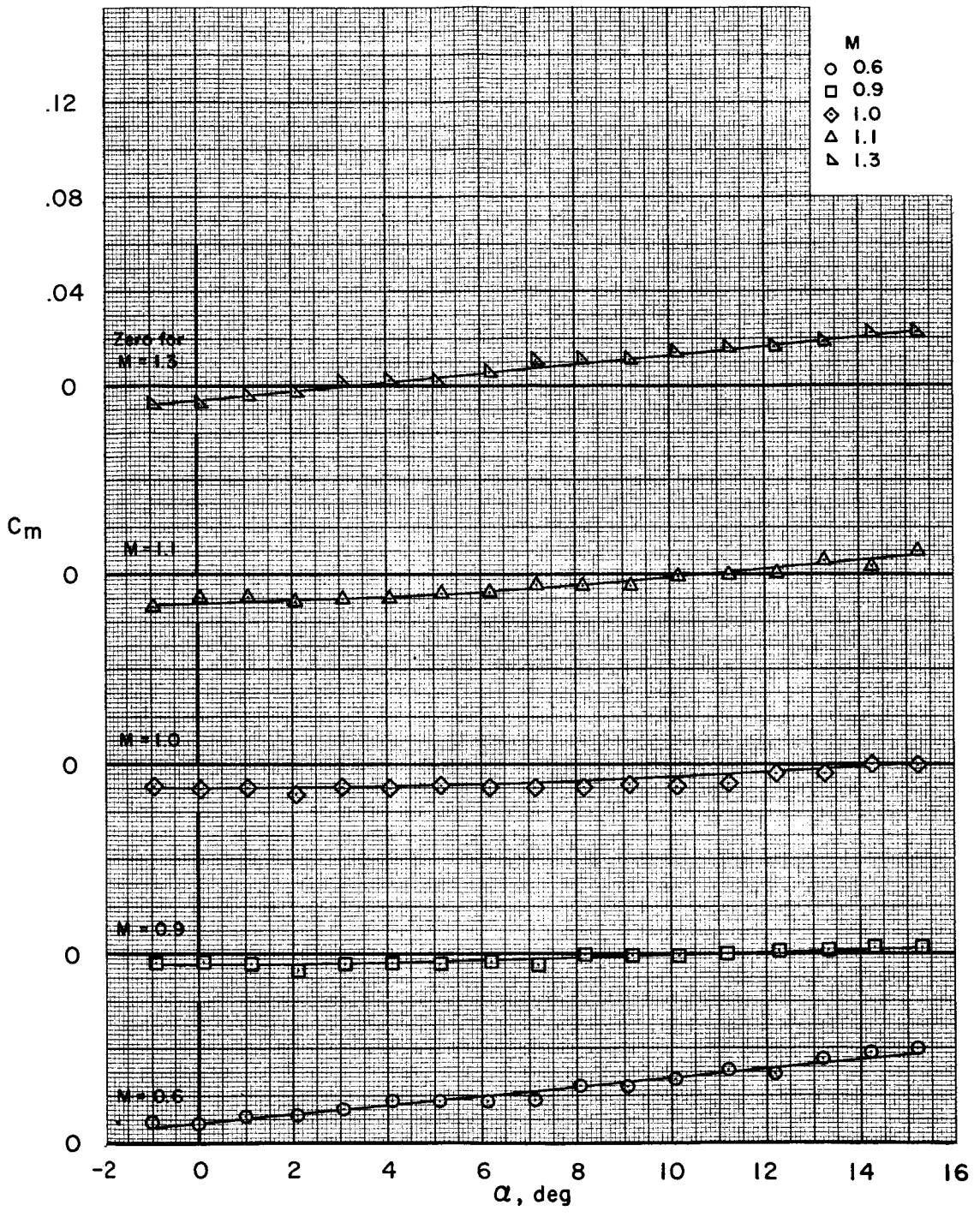
Figure 27.- Photographs of a modified 13° half-cone model (cf. ref. 8).

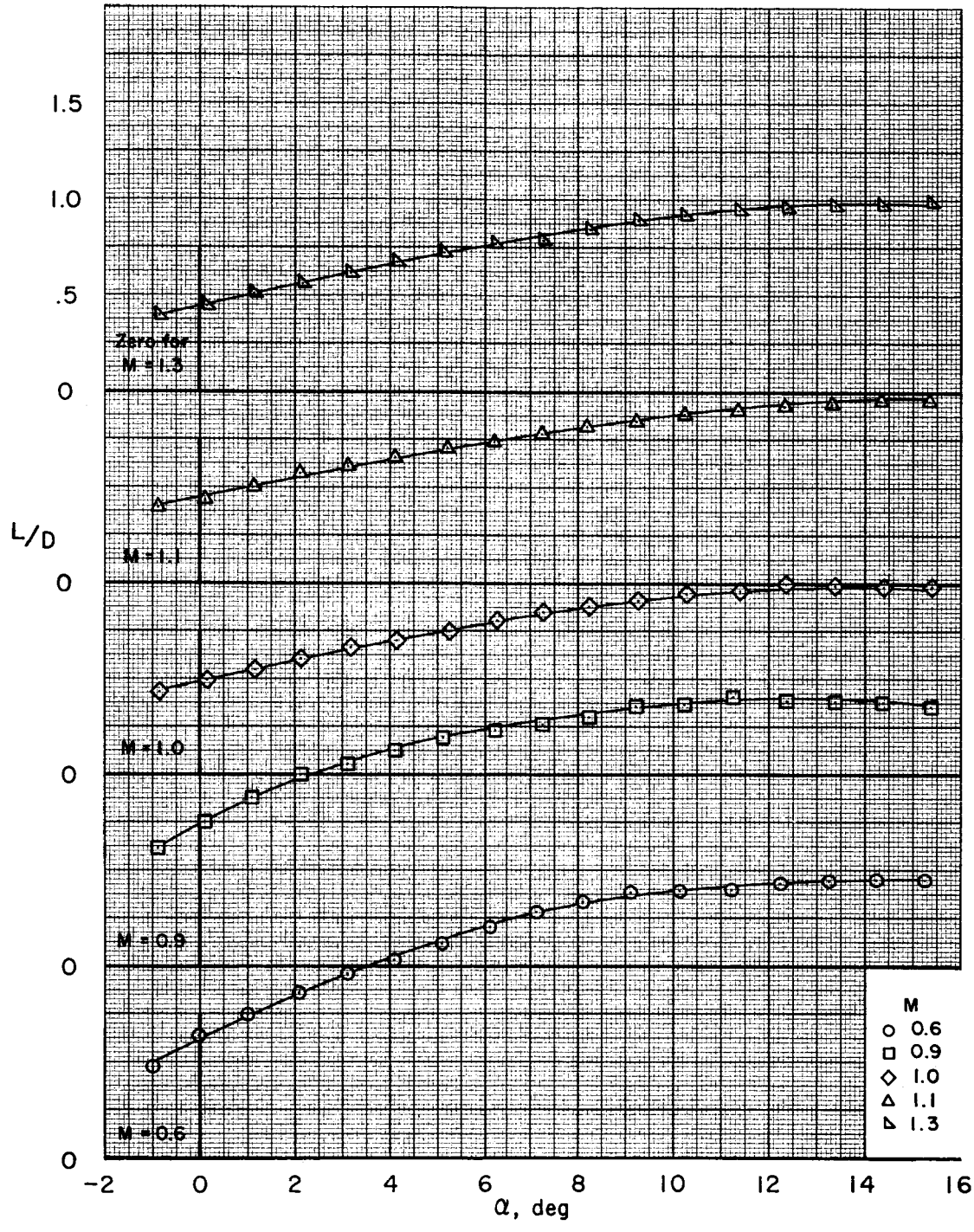


(a) Pitching moment.

Figure 28.- Low-speed aerodynamic characteristics of a modified 13° half-cone model (cf. ref. 8).

A 4 8 6

A
4
8
6



(b) Lift-drag ratio.

Figure 28.- Continued.

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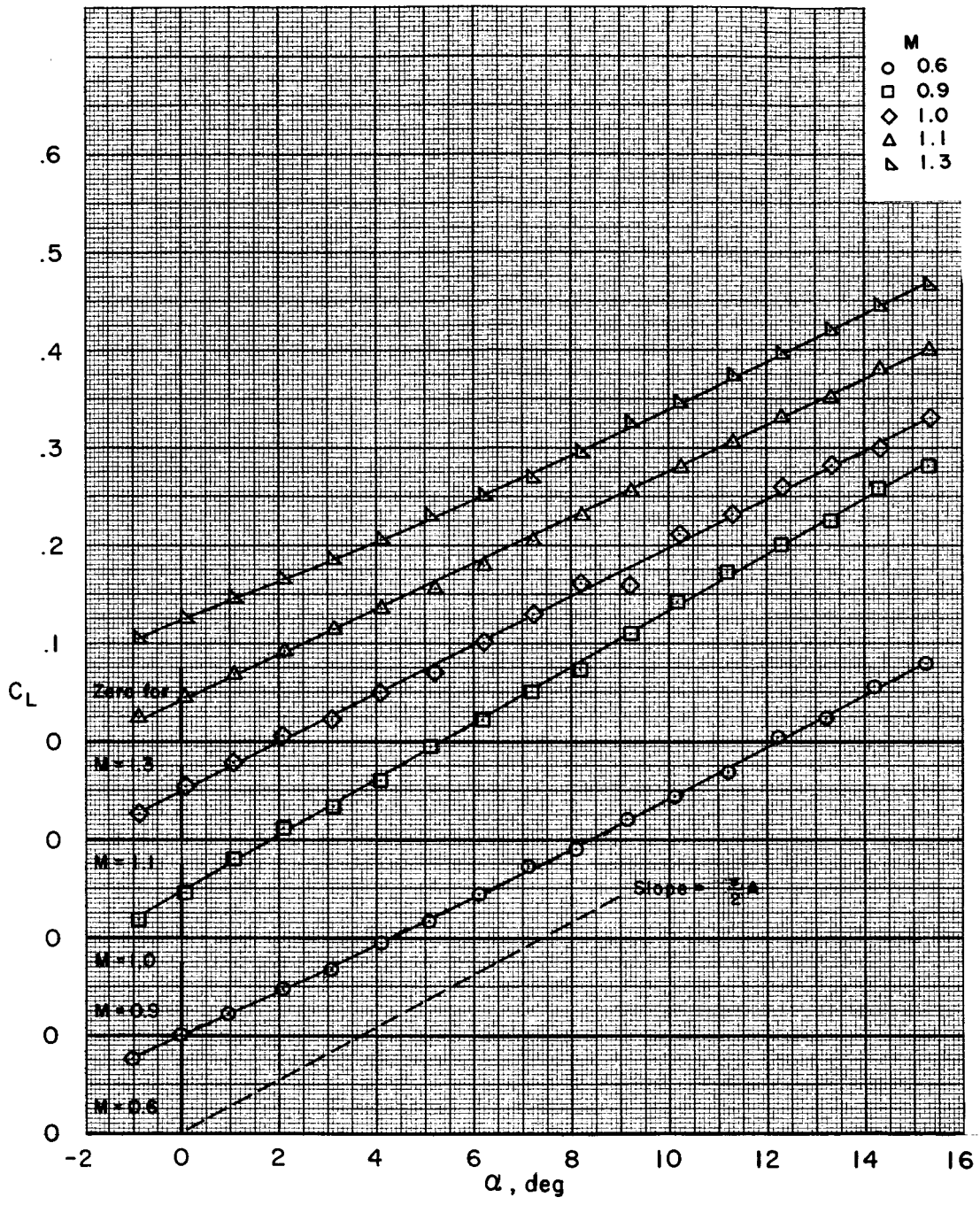
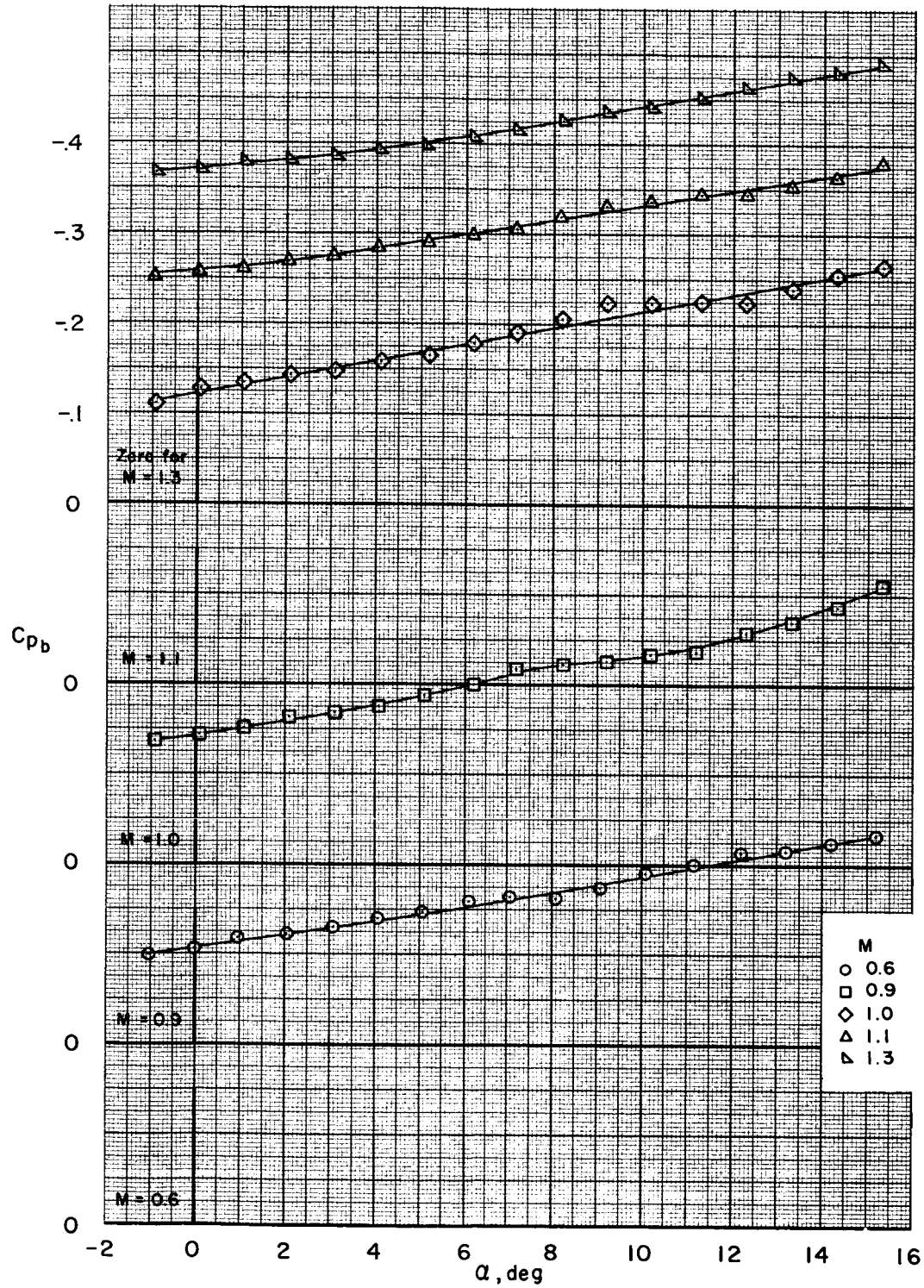


(c) Lift.

Figure 28.- Continued.

A 4 8 6



(d) Base pressure.

Figure 28.- Concluded.